Written Representations submitted in response to East Pye Solar
PINS Reference: EN0110014

Appendix: A-Q

Submitted by BEPS (Block East Pye Solar [redacted]

Appendix

Appendix A – Norfolk Barbastelle Study Group Survey Report - January 2025

Appendix B – [redacted], Botanist Letter to East Pye Solar, 2025

Appendix C – Norfolk Rivers Trust, Crayfish River Tas Crayfish evidence email

Appendix D – Hannah Fraser Consulting Ltd. (HFCL), *Independent Review of East Pye Solar Environmental Statement: Water Environment*, Report 31375R1

Appendix E – [redacted], *Independent Heritage Impact Assessment Report*, October 2026

Appendix F – Transmission Solar Developers lobbying DESNZ for Tx+Dx

Appendix G – Macquarie/DESNZ FOI Bundle

Appendix H – Macquarie/DESNZ Lobbying timeline

Appendix I - NESO Methodology FOI

Appendix J – NESO, *Gate 2 Criteria Methodology,* 12 June 2026

Appendix K – Natural England, *Definition of Favourable Conservation Status for Barbastelle Bat*, RP2974, Edition 1

Appendix L – Tinsley et al. (2023), 'Renewable energies and biodiversity: Impact of ground-mounted solar photovoltaic sites on bat activity', *Journal of Applied Ecology*

Appendix M – Barré et al. (2023), 'Insectivorous bats alter their flight and feeding behaviour at ground-mounted solar farms', *Journal of Applied Ecology*

Appendix N – Carvalho et al. (2025), 'Plant and soil responses to ground-mounted solar panels in temperate agricultural systems', *Environmental Research Letters* 20 024003

Appendix O – ADAS/Welsh Government, *The Impact of Solar Photovoltaic Sites on Agricultural Soils and Land*

Appendix P – ISEP, *Solar PV on Agricultural Land – Essential Components of Environmental Assessments and Reports,* 12 January 2025

Appendix Q – Personal Impact Statements by BEPS members

Norfolk Barbastelle Study Group

BARBASTELLE MATERNITY COLONIES IN THE EAST PYE SOLAR SCHEME AREA AT DECEMBER 2025

Author: [redacted]

1. Introduction

The work of the Norfolk Barbastelle Study Group, a specialist group within Norfolk and Norwich Bat Group, has shown that the South Norfolk Claylands support maternity colonies of Western Barbastelle Barbastella barbastellus. This species is rare in both in the UK and across Europe and one of only two of our UK bat species to be listed as 'Near Threatened' globally on the IUCN Red List. Guidance on the conservation of barbastelles is provided by Natural England's Favourable Conservation Status (FCS) document.

Although landuse in the South Norfolk Claylands is predominantly arable, the landscape is typified by scattered woodlands, high hedges, pollarded trees, open fields and commons. These habitats provide sufficient roosting and foraging resources and landscape connectivity to support a metapopulation of barbastelles.

The Core Sustenance Zone (CSZ) of barbastelles is a 6km radius around the maternity colony (Collins, 2023). The CSZ of 6 colonies lies within or abuts to the East Pye Solar Scheme area. Two colonies are next to the proposed cable route, and one of these will also be surrounded by solar panel arrays. Furthermore, there are other woodlands along the scheme area which have not been surveyed for barbastelle, particularly at the east end of the scheme area.

2. Aims and objectives

The 2025 work aimed to:

- Assess the potential of woodlands not previously surveyed for their potential to support barbastelle maternity colonies, especially at the east end of the East Pye solar scheme area
- Confirm the presence orlikely presence of barbastelle maternity colonies in these woodlands
- Identify all barbastelle maternity colonies where the East Pye solar scheme proposals may impact directly on the colony or its Core Sustenance Zone

3. Methodology

3.1 Woodland sites

Five woodlands immediately adjacent to or between 100m and 400m of the East Pye Solar scheme area were selected for survey. Three are County Wildlife Sites (CWS) with mature woodland, one is a SSSI designated for its ancient woodland and two are predominantly coniferous plantation containing stands of mature broad-leaved woodland (Table 1).

Landowner permission was obtained to survey all sites. Brooke Wood was divided into two blocks (west and east) due to its large size (64 ha).

Table 1. Woodlands surveyed in 2025

Site name	Location	Size (ha)	NGR	Designation
Spring Wood	Hempnall Green	55 2.76 mature oak belt	TM248919	CWS 90
Little Wood	Shotesham	20	TM253974	SSSI
Brooke Wood West of central track	Brooke	36 2.0 mature oak belt	TM 270985	CWS 115
Brooke Wood East of central track	Brooke	28 1.2 mature oak belt	TM 270985	CWS 115
Lower Spring Wood	Woodton	4	TM 284957	CWS 107
Round Wood	Woodton	1.5	TM 285963	CWS 108

3.2 Assessment of Roost Potential for barbastelle (BarbRP)

Each woodland was visited between January and February when Potential Roost Features (PRFs) were not obscured by foliage. Bright, sunny days were chosen to improve detection of PRFs at height. The walkover followed rides and tracks, but deviated into broad-leaved compartments in the coniferous woods and to get a closer view where needed. Trees were scanned from ground to crown with binoculars.

A broad assessment of BarbRP was made by recording the presence of PRFs specifically favoured by barbastelle, namely loose, lifted bark (bark collars, bark slabs, splits in bark) and deep cracks and fissures, regardless of height on the tree. The proportion of damaged, dying and dead trees was also noted.

3.3 Acoustic surveys

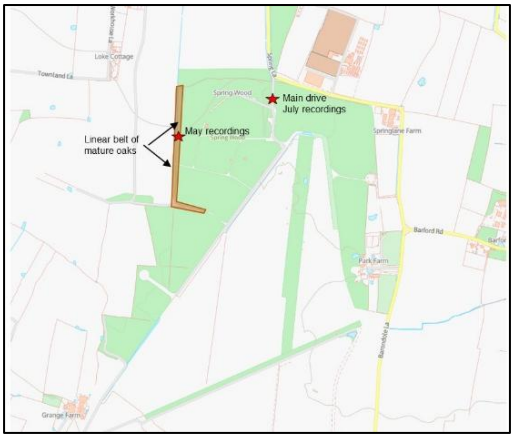
Recent work by O'Malley *et al* (2023) investigated the use of bat detectors to predict the presence of a maternity colony of barbastelles in a woodland. The research concluded that the number of barbastelle calls recorded from sunset to 1 hour after sunset is indicative of the presence of a maternity roost with a threshold of four barbastelle passes recorded by at least one detector between the true- and false-positive rates. This method requires that:

i) To maintain a 90% probability of detecting colonies where they are present, detectors should be placed at a minimum density of 0.16 detectors ha per hectare for three nights.
ii) Detectors should be placed along trails and rides where possible. Approximate equal spacing should be maintained but opportunistic placement of detectors is acceptable.

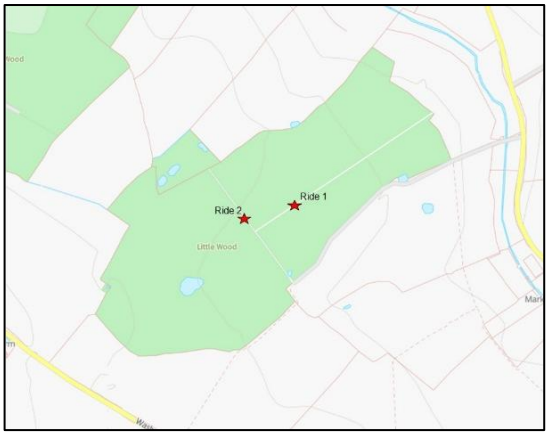
This approach is much less labour intensive and less expensive that radiotracking. Consequently, the method was used to increase the number of woodland sites in or close to the East Pye Scheme area that could be investigated in 2025.

Audiiomoth full spectrum recorders were attached to poles at 1.5m above the ground and orientated horizontally towards the likely flight path (usually a ride) or, where there was no obvious flight path within the mature oak belts in coniferous plantation, towards clearings amongst trees with high roost potential for barbastelle. Sampling rate was set to 192 and recording time was from 1 hour before sunset to 1 hour after sunrise and continuous over a minimum of 3 nights. The data was analysed using the BTO Acoustic Pipeline https://bto.org/pipeline. All barbastelle calls at lower than 0.8 confidence level were discarded but in practice there were very few.

The locations of the Audiomoths in each woodland block are shown below.



Spring Wood, Hempnall Green
No rides or clearings in mature oaks. Detector was located within the belt facing the woodland edge. Second detector on edge of main drive.



Little Wood
Two detectors on rides

Brooke Wood west and east
Detectors within the belt of mature oaks facing a clearing

Lower Spring Wood. *Detector on the edge of a short track in south west corner.*
Round Wood. *No rides or clearings. Detector amongst mature oaks and fallen ash.*

Audiomoths were deployed in Little Wood and Spring Wood Hempnall in May (the pre-parturition period) prior to attempting to trap and radiotrack pregnant female barbastelles to confirm the presence of maternity roosts. Brooke Wood, Lower Spring Wood, Round Wood were investigated using the acoustic method only. For these woods, Audiomoths were deployed in July which is the main maternity period when females have given birth and are suckling their dependent young. Additional acoustic recordings were made in the belt of mature oaks and on the main drive of Spring Wood Hempnall prior to a second trapping attempt.

3.4 Radiotracking to locate maternity colonies

All trapping and radiotagging was carried out under Natural England project licence 2024-69803-SCI-SCI. Mist nets were deployed at the north end of the central concrete track in Spring Wood Hempnall since there were no rides in the broad-leaved compartment and no access to other rides in the coniferous plantation. Nets were deployed on the 2 main rides through Little Wood. Biotrack Pip3 (< 0.46g) transmitters were attached to the skin between the shoulder blades

exposed by fur clipping using Torbot medical bonding cement. Tagged females were located daily in the roost trees and emergence surveys carried out for several nights to determine colony size.

4. Results

4.1 Barbastelle Roost Potential (BarbRP)

All woodlands had suitable roost features for barbastelle, although some were confined to small areas of broad-leaved woodland within large coniferous plantations. Little Wood has a particularly high frequency of roost features.

Table 2. Assessment of woodlands for Barbastelle Roost Potential

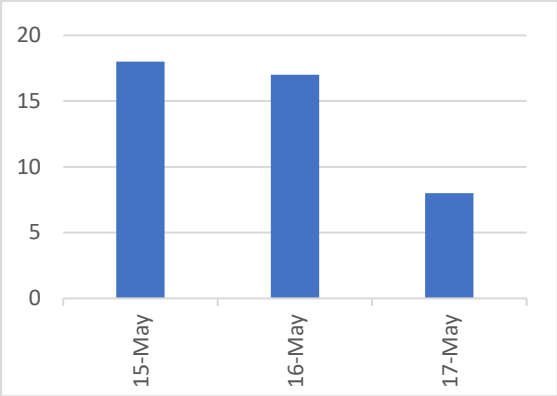
Site name	Description	BarbRP
Spring Wood Hempnall Green	A former WW2 airfield now managed as a commercial conifer plantation. Mature conifers interspersed with young ash. Hornbeam on some boundaries. A linear compartment of mature oaks runs north to south along the west side of the wood bordering the adjacent arable land. This extends east into the wood a short distance.	Mature oaks are tall with some obvious damage and deadwood in the crown. One dead oak with loose bark on the trunk in the central area. Access limited to south of wood. **MODERATE**
Little Wood	Ancient coppice-with-standards woodland. The standard trees are mostly pedunculate oak and ash and the main coppice species is hornbeam.	Numerous tall oaks and ash with damage in the crown. Loose bark at all heights. Several fallen ash trees with split bark. **HIGH**
Brooke Wood West of central track	Ancient woodland, predominantly managed as a commercial conifer plantation, divided into compartments by an extensive network of rides. Several compartments consist entirely of broadleaved semi-natural woodland, dominated by ash and oak. One linear compartment consists of broadleaved woodland dominated by oak	Mature conifers interspersed with young broad-leaved trees (beech, sycamore, oak, hornbeam) with no PRFs. A wide band of tall mature oaks running west to east adjacent to the south ride. Most have damage in the crown with loose bark visible. Evidence of acute oak decline. Several dying trees with loose bark at a low level. **MODERATE**
Brooke Wood East of central track	As for Brooke Wood West	As for Brooke Wood West. Wide band of tall mature oaks running west to east adjacent to the south ride. Damage in the crown with loose bark visible. Evidence of acute oak decline. Several dying trees with loose bark at a low level. **MODERATE**
Lower Spring Wood	Mature woodland dominated by ash, some of which arise from coppiced stools. Occasional oak and planted conifers.	Numerous dying and dead ash. Some splits in bark evident but not lifted. Woodpecker holes, rot holes and damaged trees. *See Appendix 1 for photographs* **MODERATE**

Round Wood	Mature hornbeam from former coppice with mature oak and ash throughout.	Mature oaks on west side with numerous PRFs. Several large fallen ash with loose bark. **MODERATE**

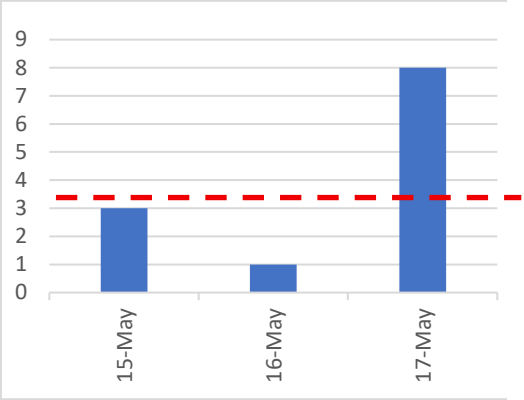
4.2 Acoustic surveys

Little Wood

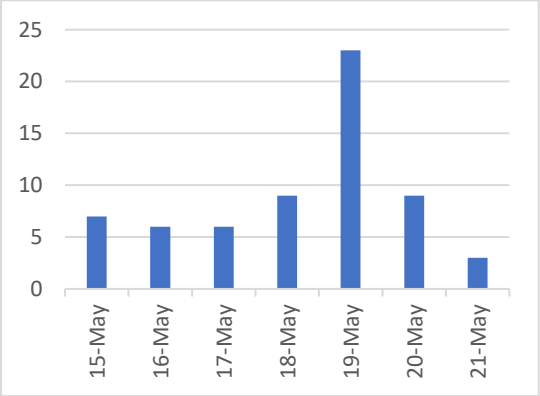
Barbastelles were frequently recorded in both rides in the wood in May with the threshold of 4 or more calls reached on several nights.



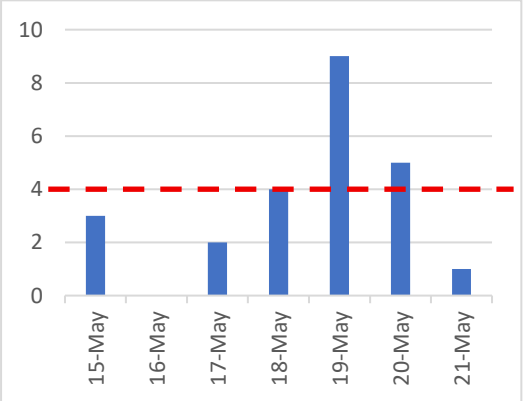
Ride 1. **May**. Calls from dusk to dawn



Ride 1. **May.** Calls from sunset to 1 hour after



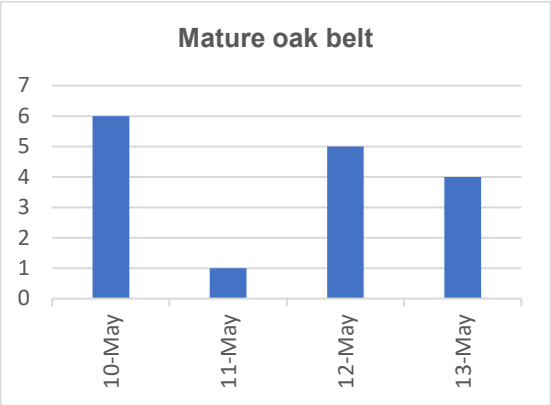
Ride 2. **May**. Calls from dusk to dawn



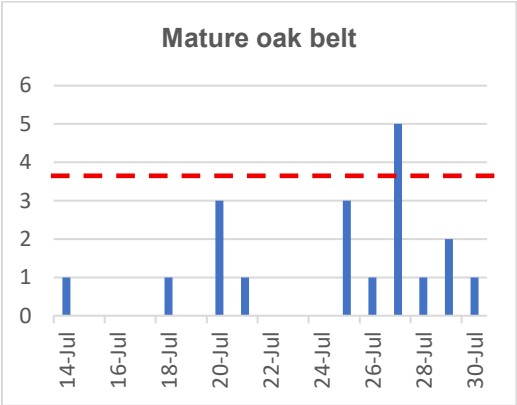
Ride 2. **May**. Calls from sunset to 1 hour after

Spring Wood, Hempnall Green

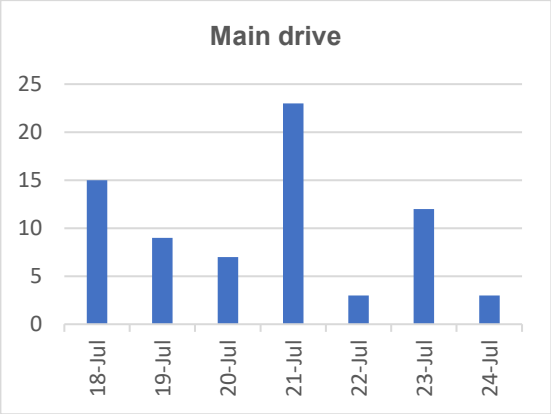
Barbastelle calls were recorded on all nights within the mature oak belt in both May and July, but only exceeded 4 calls on a single night in July. Activity was higher along the main drive in July but few calls were recorded in the hour after sunset.



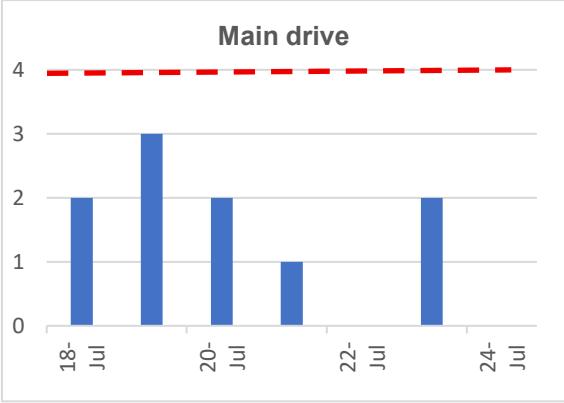
May. Calls from dusk to dawn
No calls from sunset to 1 hour after



July. Calls from dusk to dawn
A single call from sunset to 1 hour after sunset



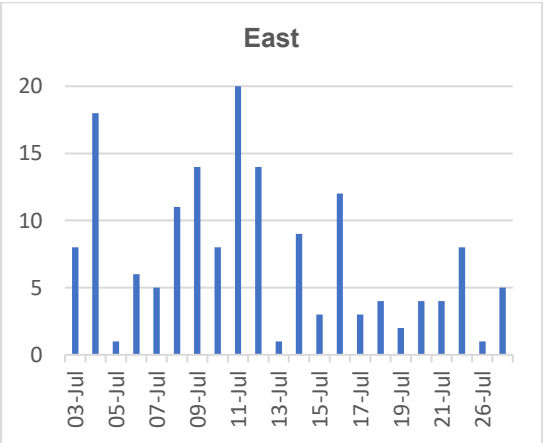
July. Calls from dusk to dawn



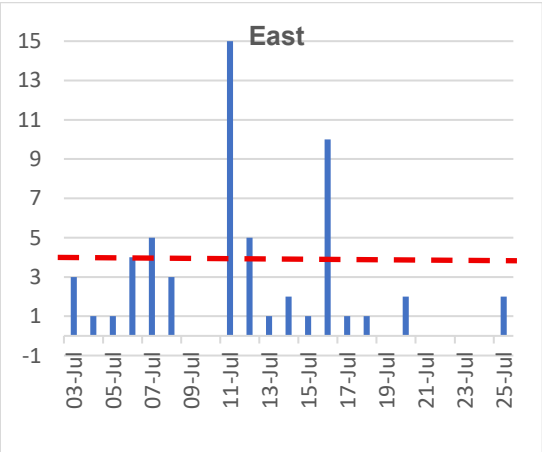
July. Calls from sunset to 1 hour after sunset
Threshold of 4 calls not reached.

Brooke Wood East

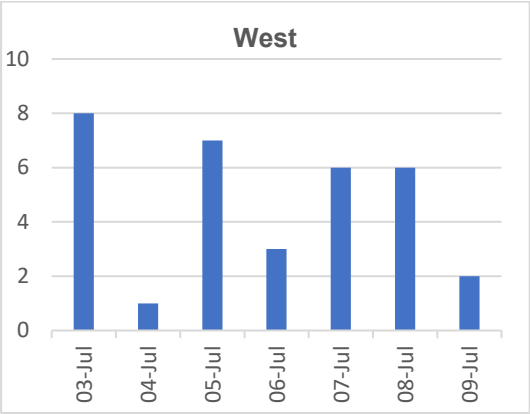
Barbastelle calls were recorded on all nights in July in both east and west sides of the mature oak woodland belt. The threshold of 4 calls in the hour after sunset was reached on 4 nights, with a peak of 15 calls on July 11th. Barbastelle calls were recorded on the west side of Brooke Wood on all nights in early July but less frequently than on the east side and the threshold of 4 calls in the hour after sunset was not reached.



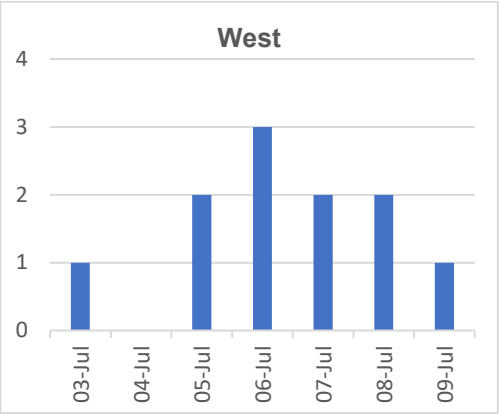
July. Barbastelle calls from dusk to dawn



July. Barbastelle calls from sunset to 1 hour after



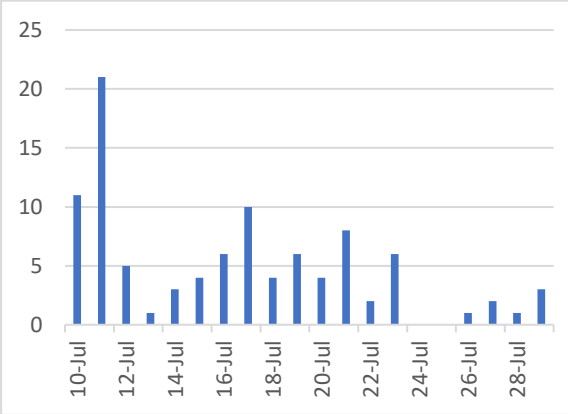
July. Barbastelle calls from dusk to dawn



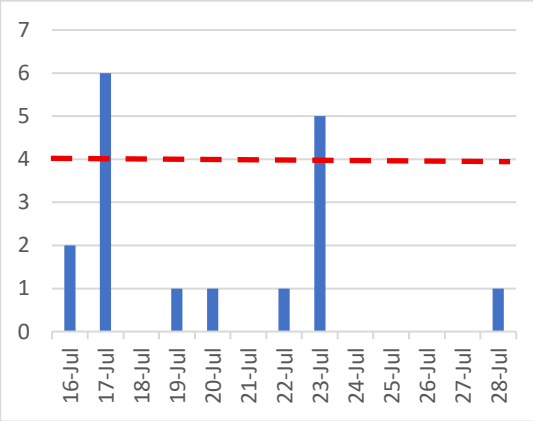
July. Barbastelle calls from sunset to 1 hour after

Lower Spring Wood Woodton

Barbastelle activity was recorded on nearly all nights, exceeding the 4 call threshold on 2 nights.



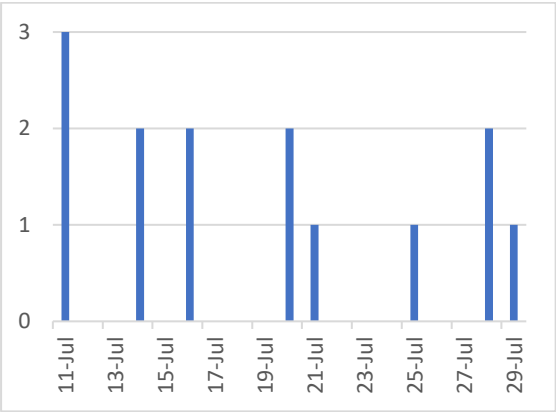
July. Barbastelle calls from dusk to dawn



July. Barbastelle calls from sunset to 1 hour after.

Round Wood Woodton

A few barbastelle calls were recorded on most nights but none within the hour after sunset.



July. Barbastelle calls from dusk to dawn
No calls from sunset to 1 hour after

4.3 Radiotracking

Spring Wood, Hempnall Green

Three trapping sessions were carried out on the main drive but no female barbastelles were trapped. A single male was caught on 1st August.

Date	Barbastelle	Other species
2nd June (pre-parturition)		Common pipistrelle x 6 Soprano pipistrelle x 3 Brown long-eared x 1
25th July (post-parturition)		Common pipistrelle x 6 Soprano pipistrelle x 2 Brown long-eared x 17
1st August (post-parturition)	1 adult male	Common pipistrelle x 1 Soprano pipistrelle x 1

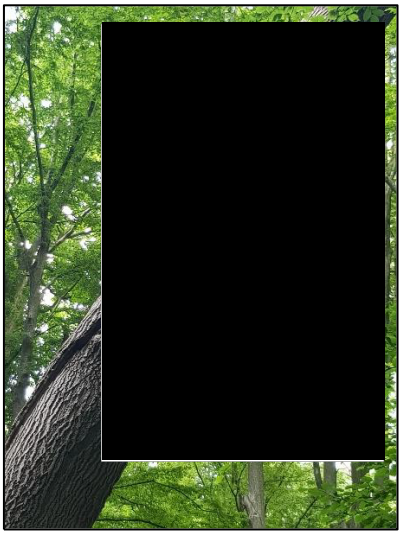
Little Wood

Three female barbastelles were caught during the single pre-parturition trapping session. Two were assessed as pregnant and radiotagged. Roosts were located over the next 7 days and emergence counts carried out.

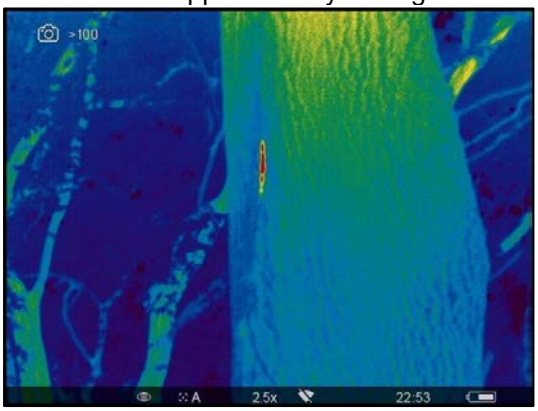
Date	Roost tree	Emergence count
6th June	Both bats in oak (R1) close to trapping location. Possibly a panic roost. Roost obscured by surrounding vegetation. Tagged Bats emerged at 14 and 16mins after sunset	
7th June	Thunderstorms in day and evening. No tracking	
8th June	Both bats in leaning ash (R2) with split bark in Little Wood	29
9th June	Both bats in R2	36
10th June	Both bats in R2	36
11th June	Both bats in R2	28
12th June	Both bats in R2. 1 tag detached	25

The roost tree used for 5 days continuously was a very tall ash which was still alive but leaning over and supported by adjacent trees. The trunk had twisted causing the bark to split and lift. The maternity roost was at the top end of the split.

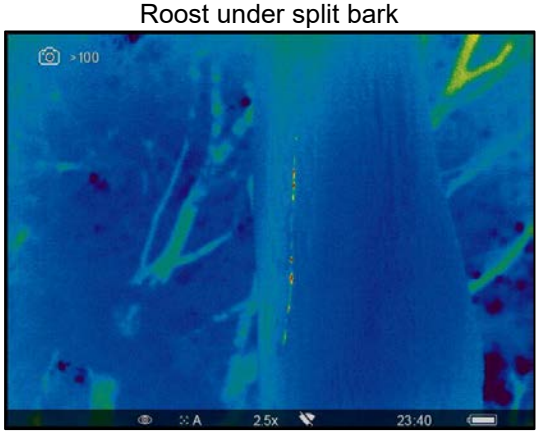
Roost approximately 4m high



Roost under split bark



Thermal image of colony under loose bark



Colony before emergence, moving around along the length of the split

5. Discussion

A new maternity colony was predicted to be present in Little Wood near Shotesham by assessment of BarRP and acoustic analysis and was subsequently confirmed by radiotracking. The peak pre-parturition count was 36, and the post-parturition count is expected to be approximately 55 which is large in the context of Norfolk maternity colonies.

The acoustic method also predicts the presence of barbastelle maternity colonies in the mature oak belt in Brooke Wood and in Lower Spring Wood at the north east end of the solar scheme. It is uncertain if a maternity colony is present in Spring Wood Hempnall. Trapping was very much constrained by the lack of rides near the mature oak belt. The timing of calls, the trapping results and previous acoustic surveys (Mick Finnemore, personal communication) confirms that barbastelle roosts are present and the woodland is used for roosting and feeding. Further work is needed to confirm roost status.

A significant outcome of the work has been to show that small stands of mature oaks embedded within large coniferous plantations can support maternity colonies, provided that suitable roost features are present. Coniferous plantations should not be dismissed without detailed assessment.

Previous work in Norfolk has shown that oak and sweet chestnut are the major tree species used by barbastelles in north and west Norfolk. Ash and hornbeam are the predominant species in many South Norfolk woods, with oak often having often been removed during the WW2. Much of

the ash is now ageing and badly affected by ash dieback which is generating roost features for barbastelle, especially splits in loose bark (Appendix 1). The importance of ash woodlands as a roost resource for barbastelles in South Norfolk is likely to increase and should not be underestimated.

The map of barbastelle maternity colony CSZs is now updated for this new data (Figure 1). Further radiotracking is needed to confirm the presence of maternity colonies in Brooke Wood, Lower Spring Wood and Spring Wood Hempnall. Other woodlands within or close to the solar scheme area should be assessed regardless of size and investigated for the presence of maternity colonies. Candidate woods are the remaining two woodlands of the four Shotesham-Woodton Hornbeam Woods SSSI, namely Hempnall Little Wood and Winters Grove. Saxlingham Grove is already known to support a maternity colony. Ringers Grove is an ash wood of similar age to Lower Spring Wood. Tindall Wood, Sexton Wood, Hedenham Wood and Park Plantation are at the east end of the scheme area and should be assessed. There are many small scattered woodlands west and east of Hempnall which may provide a roost resource for the barbastelle metapopulation. The impacts of the East Pye Solar Scheme on barbastelles cannot be properly assessed without a full understanding of barbastelle distribution and habitat use within the scheme area.

6. References

Collins, J. (ed.) (2023) *Bat Surveys for Professional Ecologists: Good Practice Guidelines (4th Edition)*. The Bat Conservation Trust, London

O'Malley, K.D. *et al*. (2023), *An acoustic-based method for locating maternity colonies of rare woodland bats.* PeerJ, DOI 10.7717/peerj.15951.

7. Acknowledgements

Thanks are due to [redacted] for preparing the maps of barbastelle maternity colony Core Sustenance Zones and to [redacted] for use of the BTO Acoustic Pipeline. I am also grateful to members of Norfolk and Norwich Bat Group who assisted with the trapping.

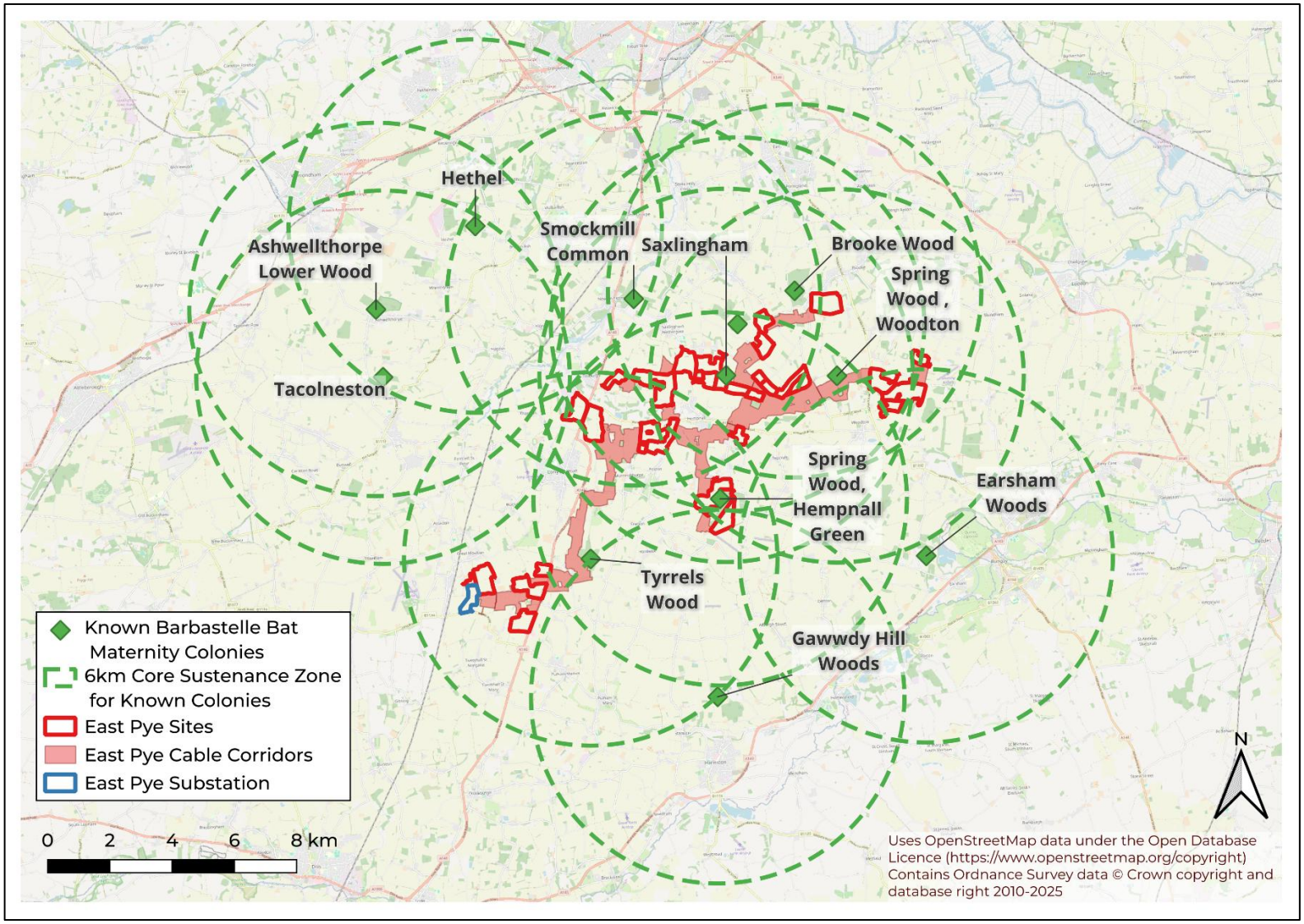
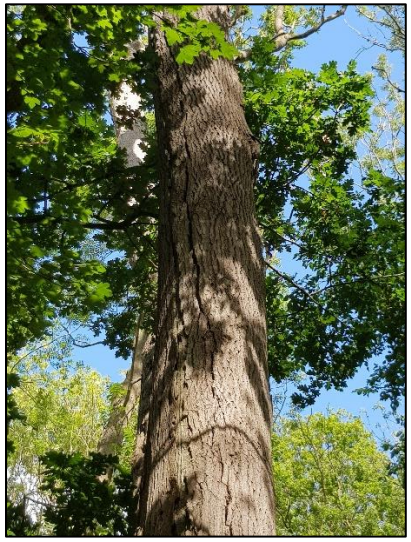


Figure 1. Core Sustenance Zones of Barbastelle Maternity Colonies within or close to the East Pye Solar Scheme Area

Appendix 1. Photographs of split and lifting bark in mature ash trees in Lower Spring Wood, Woodton



30th January 2026

To Whom It May Concern,

We write to express concern that the Preliminary Environmental Information Report undertaken by East Pye Solar does not contain evidence of systematic botanical recording across the sites which will be part of, affected by, or potentially affected by the proposed solar farm. We ask

- **that botanical walkover surveys should be undertaken across the full affected and potentially affected area by a botanist of FISC level 5 of above, one in June to document grassland vegetation, and one after the harvest but before sowing, to document arable field vegetation,**
- **and that this evidence, along with modified scheme proposals which avoid damage to botanically valuable areas, be submitted to public consultation before the PEIR is admitted for consideration by the planning inspectorate, and before the scheme layout or cable routes are fixed.**

Under EIA Regulations 2017, Schedule 4, the applicant must describe 'the likely significant effects of the development on biodiversity, with particular attention to species and habitats'. The extended habitat surveys, habitat mapping and classification, and desk-based flora study undertaken by the applicant do not discharge this duty where rare or notable plant species may be present, where land has long agricultural continuity, or where boundary features are affected. As all of these circumstances apply to the EPS area, **the signatories of this letter, both botanists with in-depth knowledge of this landscape and its flora, formally object to a full application based on the current PEIR documentation.**

Rare or notable plant species

We know from our own botanical records that Sulphur Clover, *Trifolium ochroleucon*, is found at multiple sites where modification of road verges is planned – these include but are not limited to Market Lane (TM2596/2597/2598), Woodton Road (TM2796/2795), Wood Lane/Tyrrell's Wood (TM2089), Bussey's Loke/Fyland's Road (TM2595/2695, and Lodge Road/Hundred Lane/Carpenter's Walk (TM1788/1888). Sulphur clover is a scarce plant in GB, and on the Red Lists for GB (Endangered) and England (vulnerable). Road verges are the major habitat for this plant (perhaps 95% of cases), and South Norfolk is one of its strongholds, supporting around 20% of the national population. It often grows in narrow strips along a verge, perhaps

50cm in width, which makes it particularly vulnerable to road widening or pressure from large vehicles.

The area is also home to Norfolk's major communities of the locally scarce Dyer's Greenweed/Petty Whin, *Genista tinctoria*, a strikingly beautiful low-growing broom, which is categorised as Endangered on the GB Red List. The Lodge Road/Hundred Lane/Carpenter's Walk/Prangle Lane area of tracks contains the best colony of Dyer's Greenweed in Norfolk, and is only spot where the notable trio of Dyer's Greenweed, Sulphur Clover, and Spiny Restharrow, *Ononis spinosa* grow together. Woodton Road (TM2796/2795) is the location of Norfolk's largest road-verge colony of Dyer's Greenweed, which is also found at Wood Lane/Tyrrell's Wood (TM2089) and Lodge Road/Hundred Lane/Carpenter's Walk (TM1788/1888). This species has only eight extant locations in the county, up to five of which are within the area affected by the scheme.

Other noteworthy verge species include

- Crosswort, *Cruciata laevipes*, *which is* Near-threatened on the England Red List, at Wood Lane/Tyrrell's Wood (TM2089)
- Pepper saxifrage, *Silaum silaus*, which is Endangered on the GB Red List, at e.g. Lodge Road/Hundred Lane/Carpenter's Walk/Prangle Lane area, Bussey's Loke/Fylands Road/Saxlingham Green/Wash Lane area, Wood Lane/Tyrrell's Wood, Woodton RoadMarket Land

We estimate that locally there are at least 88 threatened species (as per GB Red List 2025) in the area affected by the plans, although this would need confirmation from a full botanical survey. However, at least as significant as individual rare and notable species are the species assemblages found at many of these sites, with several combinations of key local species occurring only once or a very small number of times - relict populations of communities which would have been widespread before agricultural intensification, and which are often the last remains of historic boulder clay pasture or roadside commons. Due to the ancient origins of such hotspots they will often be associated with specific symbiotic fungi (known at e.g. Market Lane and Woodton Road) and would not be replaceable by planting seed elsewhere, meaning that avoidance of harm is vital.

While we have sufficient records of Endangered and other noteworthy species to know that this is an extremely botanically significant area, its botany has been systematically under-recorded and there is a good chance that many valuable pockets have been missed, making full walkover surveys of all sites which are currently included within plans, or may be included in future, by botanists with a high skill level (FISC 5 or above), absolutely necessary.

Boundary features

Any parish boundaries which may be affected by the scheme should be fully surveyed. These should certainly include, but not be limited to,

- the Woodton Road boundary between Shotesham/Brooke/Woodton
- the cluster of lanes Bussey's Loke/Saxlingham Green/Fylands Road/Wash Lane, which sit on and near the boundaries of Saxlingham Nethergate/Shotesham/Hempnall. This cluster of lanes is one of the most species-rich spots in South Norfolk.
- Bustard's Green boundary between Wacton/Forncett St Peter.

Long agricultural continuity

The South Norfolk agricultural landscape shows exceptional continuity, with its glacial, boulder-laden, heavy clay plateau having resisted the horse-drawn plough for longer than much of the rest of the East of England. This precious yet fragmented time-capsule preserves the remains of the old greens, commons, and drove roads which were once plentiful across England, a value which has recently been recognised through the Norfolk Wildlife Trust's Claylands Wilder Connections and Wilder Claylands projects, which have been trying to build and strengthen the corridors between these fragments since 2021. NWT's projects are underpinned by a recognition of the higher-than-average populations of mobile wildlife which the landscape supports as well as its botanical, broader ecological, and historical value.

The area covered by the scheme is a landscape of long, quiet, narrow roads. These are characterised by wide verges which have often never been ploughed, and which are typically found in combination with drainage ditches and adjoining hedges, creating a varied set of habitats at the hyper-local scale. Notable plants and plant communities are often found growing along extremely narrow strips (as narrow as 30cm) on the verges, and are thus highly susceptible to damage by heavy traffic coming up off the asphalt onto the vegetation. Ditches can contain water plantain, water figwort, false fox sedge, meadowsweet and water mint while hedges shelter dog's mercury and early dog violet, as well as wood-edge flora like hedge bedstraw, upright hedge parsley, stone parsley, cowslip, hairy St John's wort and dewberry. While these species are not individually protected, their presence in intact if often isolated communities is noteworthy and worthy of protection. In some cases the designation Roadside Nature Reserve protects specific verge stretches, but in our opinion the area is under-designated (for example, the RNR on Woodton Road should extend to protect the whole community of *Genista tinctoria* there, and a wider area should be protected in the Hundred Lane/Prangle Lane area). These unploughed verges and their adjoining ditches and hedges are a vital living heritage, as some of the last remaining links back to the pre-industrialised and even

medieval/prehistoric agriculture once practiced in the East of England, and to the rich natural tapestry which it supported and jostled with in a pre-chemical age.

Field edges are also sites of concern, and as they are currently less well documented than verges there is an equally pressing need for survey before any irreversible changes take place. For example, Prangle Lane track, which looks like it may be affected by the scheme, is in effect a field edge of great importance, while the field entrance at Market Lane RNR is a highly valuable and irreplaceable habitat.

General observations

The sites given here are by no means a complete list of botanically valuable sites in the area – they simply try to give some sense of the botanical richness of this landscape. A full survey is needed so that the extent of any future damage under current or future plans can be fully assessed, mitigated for, and if destruction of habitat takes place, compensated for.

While the numbers of species and sites may seem a lot on paper, some cover very small areas. These last refugia of the historic landscape are now of vital importance as sources for recolonisation and for the seed production which can be used to reintroduce local species to sites from which they have been lost. This is already happening, for example under the Norfolk Wildlife Trust's Claylands Wilder Connections and Wilder Claylands project, but would be hampered by the loss of source seedbanks.

There may be the potential for a solar farm to lead to biodiversity net gain across this landscape, and perhaps existing seedbanks and botanically rich areas could be a keystone element of a future plan to rejoin currently disconnected habitats. However, if the value of existing biodiversity is not fully assessed, any future BNG claims will be meaningless, and if current species-rich habitats are not protected, ignoring the initial steps on the mitigation hierarchy *Avoid >> minimise >> restore >> offset*, the offset required is likely to be far higher than it would if damage was avoided and minimised in the first place. The loss or partial loss of sites like Market Lane (TM2596/2597/2598), Woodton Road (TM2796/2795), Wood Lane/Tyrrell's Wood (TM2089), Bussey's Loke/Fyland's Road (TM2595/2695, and Lodge Road/Hundred Lane/Carpenter's Walk (TM1788/1888) would be a disaster for local botany and the associated ecosystems, and any damage done to them would be highly unlikely to be compensated for by BNG measures due to their ancient and cultural origins. It is imperative that any scheme design submitted for consultation takes account of the valuable botanical sites and designs its site entrances, traffic arteries etc around them rather than through them, and that it seeks to enhance connectivity between patches rather than further isolate them.

Yours faithfully,

[redacted] *botanist with 30 years of South Norfolk recording experience*
[redacted]
[redacted]
[redacted] *writing in personal capacity)*

From: [redacted] Norfolk Rivers Trust [redacted]
Subject: White clawed crayfish
Date: 1 Dec 2025 at 12:25:21
To: [redacted]

Dear [redacted]

Thank you for your email. I hope the information below is helpful.

We last surveyed for white clawed crayfish in the Tas in 2022. There were 4 found, including a juvenile which indicates successful breeding on the site. It's particularly deep in the survey reach so very difficult to survey manually and due to the presence of otters and water voles, I did not want to set crayfish traps.
We also found 3 at the same location on 9th August 2021 and 2 juveniles in 2020.

I haven't had funding to do any surveys for a few years now so can't update on anything recent.

It is worth noting that the eDNA survey in 2020 came back negative however it was a new method being trialled by a student so was not a successful method to use.

Kind regards
[redacted]

[redacted]

Senior project officer

[redacted]

Norfolk Rivers Trust

15 Bayfield Brecks, Holt,

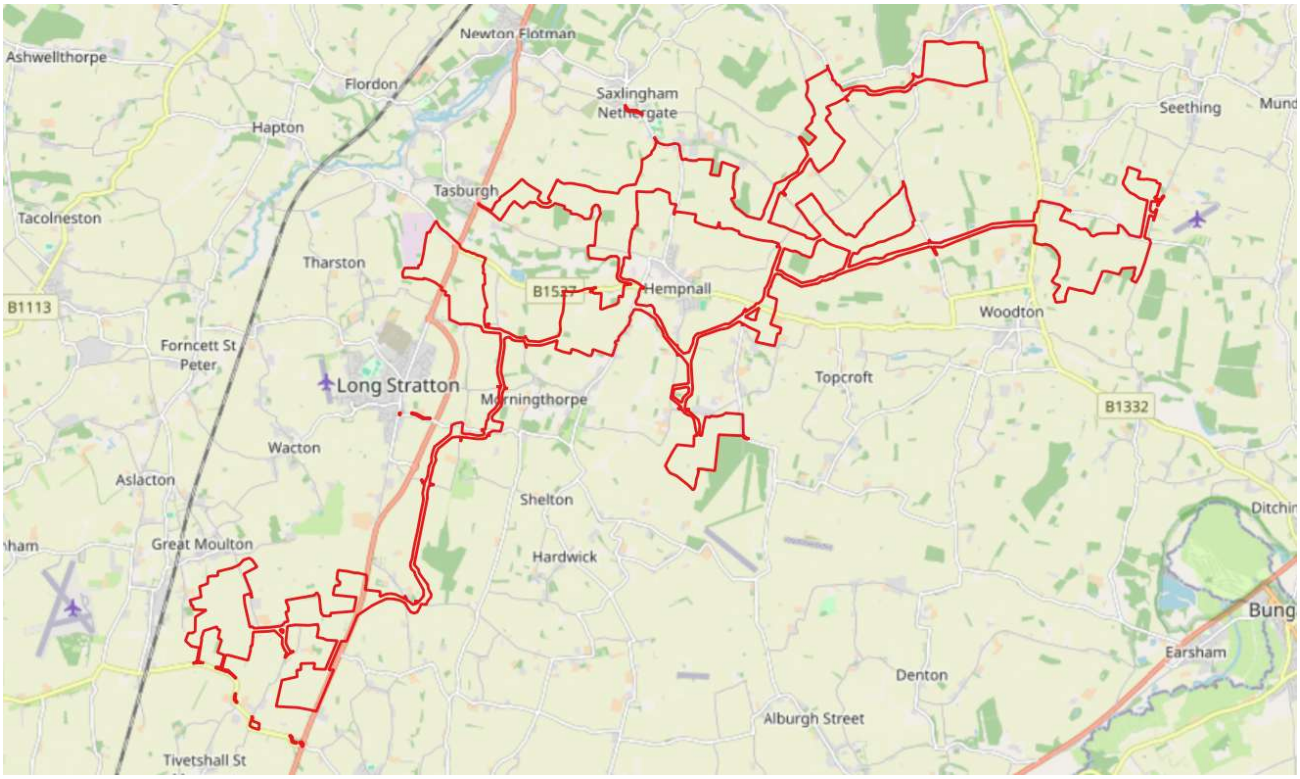
Norfolk, NR25 7DZ

norfolkriverstrust.org

H Fraser Consulting
Contaminated Land and Hydrogeology

East Pye Solar

Environmental Impact Assessment Review Report: Ground conditions, hydrology and hydrogeology



Prepared for: Block East Pye Solar

Date 28/09/2026

Status: Final

Reference: 31375R1 Rev01

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Prepared by: H Fraser Consulting Ltd

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Contaminated Land and Hydrogeology

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Version History

Version	Author	Approved by	Issue date	Comment
31375R1D1	[redacted]		28/08/2026	Draft report issued to client
31375R1			09/09/2026	Final report issued to client
31357R1 Rev01			28/09/2026	Minor amendments following client review

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GLOSSARY

BESS Battery Energy Storage System

EA Environment Agency

EPS East Pye Solar

GWDTE Groundwater Dependent Terrestrial Ecosystems

m aOD metres above Ordnance Datum

PrWS Private Water Supplies

PV Photo-voltaic

PWS Public Water Supplies

RBMP River Basin Management Plan

SPZ Source Protection Zone

WFD The Water Framework Directive 2000/60/EC of the European Parliament as transposed into UK Law by The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017

1. INTRODUCTION

H Fraser Consulting Ltd (HFCL) has been instructed by Block East Pye Solar (BEPS) to provide a critical review of the ground conditions and water resources elements of the Environmental Statement and associated documents submitted in support of the application made to the Planning Inspectorate (PINS) by East Pye Solar Ltd (the Applicant), PINS Reference EN0110014.

1.1 Objective

The objective of the work is to ascertain whether environmental impacts of the scheme pertaining to surface water and groundwater have been appropriately identified by East Pye Solar Ltd, and whether the scheme incorporates adequate mitigation to ensure that impacts to surface waters and related human and environmental receptors will be reduced to acceptable levels.

1.2 Scope of works

In undertaking the review, HFCL has reviewed those aspects of the Environmental Statement that pertain to the subject areas, including the associated Technical Appendices. The primary focus of the review was Chapter 9 (Water Resources) and Chapter 16 (Ground Conditions) and the Technical Appendices thereto. Other Chapters have been reviewed where pertinent, including Chapter 4 (The Scheme), Chapter 5 (Reasonable Alternatives and Design Evolution) and Chapter 18 (Other Environmental Matters), but we provide no comments on these chapters directly. HFCL's review has focussed on the areas of its technical specialism in assessment of ground conditions, hydrology and hydrogeology.

2 BACKGROUND

East Pye Solar (EPS) comprises the construction, operation and maintenance, and decommissioning of a ground-mounted solar photovoltaic (PV) generating station and associated development, including:

- A BESS (Battery Energy Storage System);
- A number of project substations (both 132kv and 400kv); and
- A new National Grid substation operated by National Grid Electricity Transmission plc.

The Scheme also involves grid connection infrastructure including works to the existing 400kV overhead line and associated pylon(s) (for example, the relocation or moving or the existing pylon(s), new pylons, temporary replacement pylon(s) and restringing of the overhead line). Underground electricity cabling will run between the Solar PV sites within the Cable Route Corridor (CRC) to connect to the BESS and the National Grid substation[1].

All scheme boundaries and information are based on the most up to date plans available as of June 2026.

This section is informed by desk study information, and a site visit undertaken by HFCL staff on 18th and 19th June 2026; site photographs and commentary on the site visit are presented in Appendix A.

2.1 Site setting and current use

The Site is located 11 km south of the city of Norwich, Norfolk. The indicative plan borders and intersects many smaller villages such as Long Stratton, Morningthorpe, Hempnall and Great Moulton. The site location, and boundaries are shown in Figure 2-1.

[1] https://www.eastpyesolar.co.uk/scheme-overview

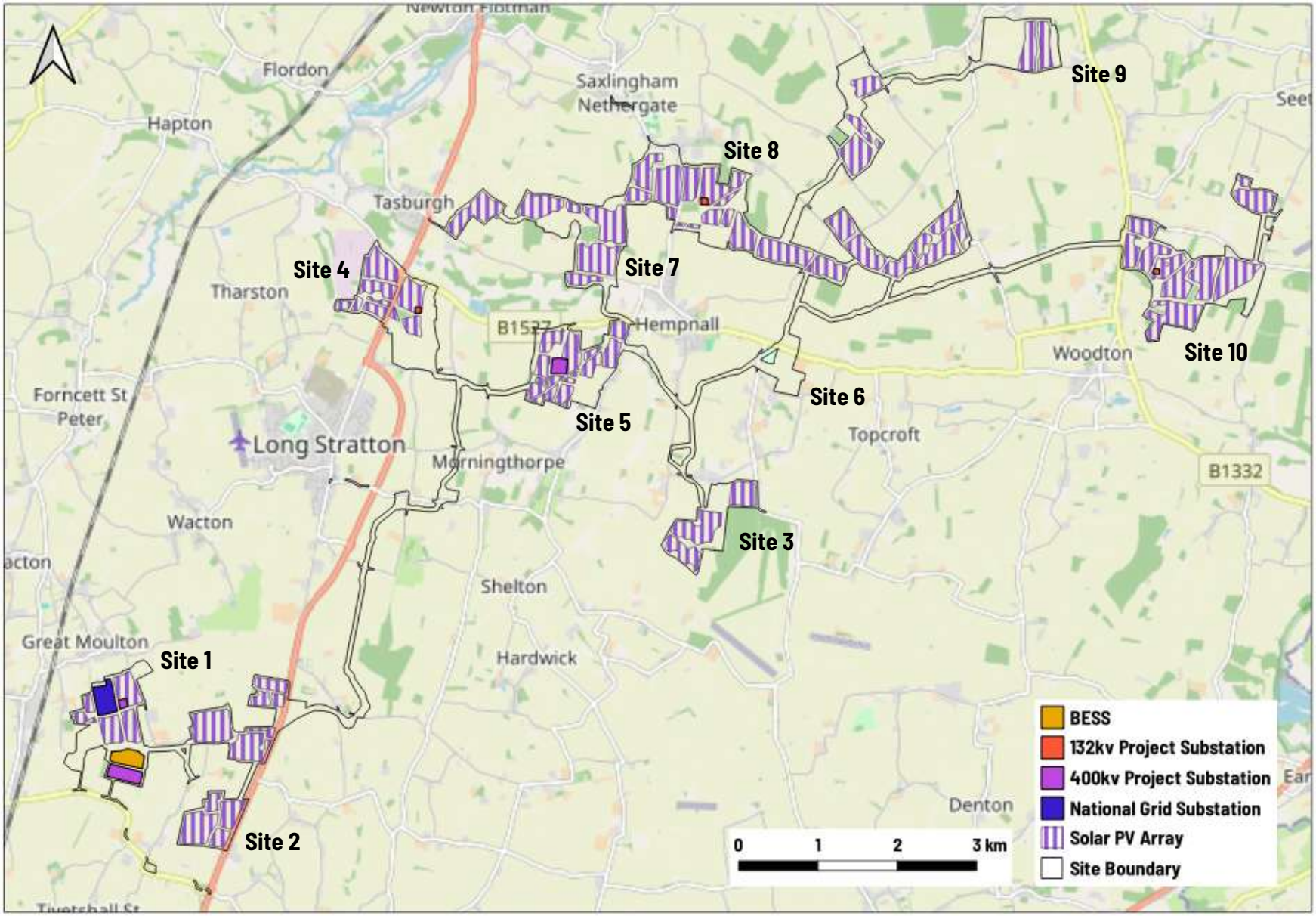


Figure 2-1 Site Location and Indicative Plans

Contains Ordnance Survey data © Crown copyright and database right 2026
EPS Indicative Masterplan, April 2026

2.2 Site description

The centre of The Site is easting 622249, northing 292893. The Scheme will cover 1,212.3 hectares (ha) of agricultural land, of which approximately 1,051 ha will host the solar panels, BESS Site and substations and approximately 159 ha of land will be within the Cable Route Corridor (CRC). There are seven highways improvement areas within the Order Limits covering a combined 2.02 ha[2].

2.3 Topography and Hydrology

The Site spans c. 17 km of varied topography which can be seen in Figure 2-2 below. The highest point is 58 m AOD in the southwest down to 22 m AOD in the middle of The Site. The Site intercepts two river catchments, the River Waveney in the south, and the River Yare in the north. A broad overview of these can be seen in Figure 2-3 below.

The Site and surrounding areas are mapped as having a generally interconnected ditch and stream network. The ditches and watercourses are reported by local residents to have a direct response to rainfall, with high water levels (both groundwater and watercourse levels) in the wet winter months.

Several springs are mapped in the area[3]. One spring was located on the site visit to Elder Farm/The Forge, situated next to Site 1.

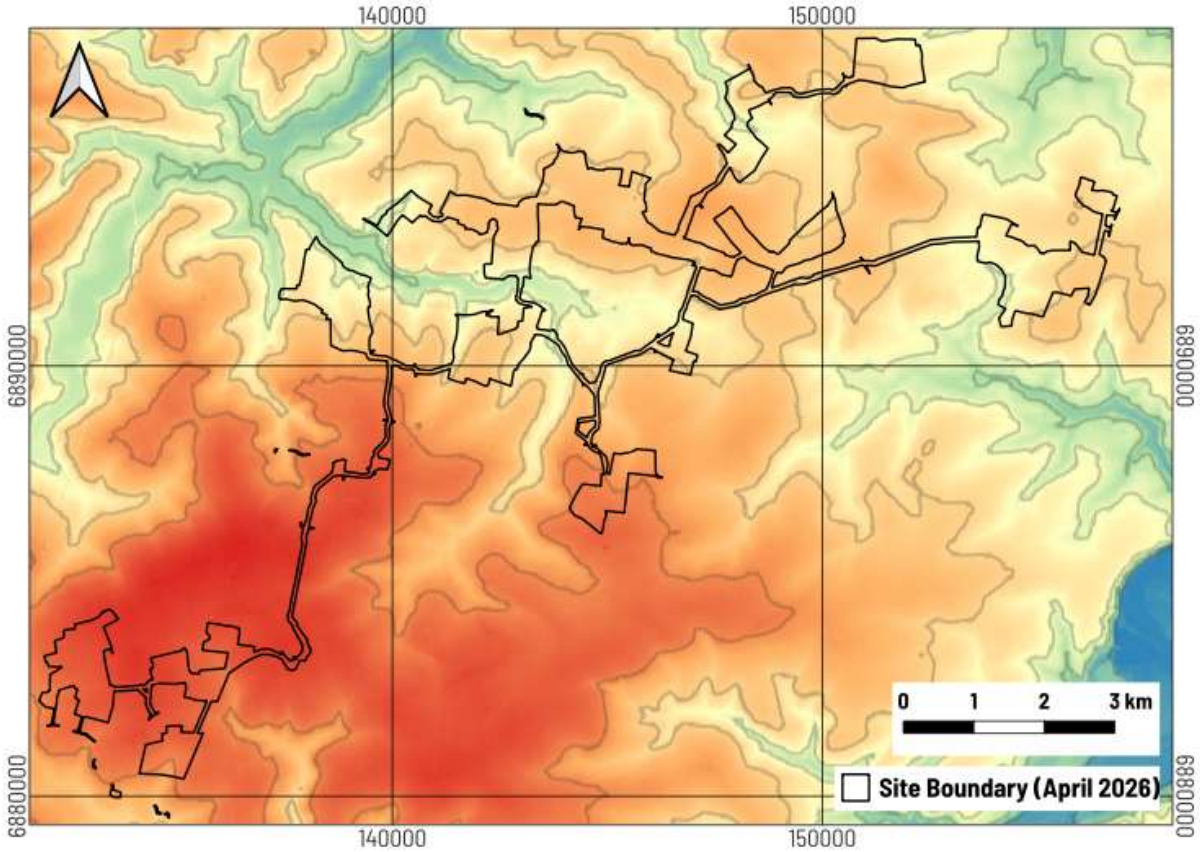


Figure 2-2 Site Topography

National LiDAR programme, © Environment Agency copyright and/or database right 2025. All rights reserved
Based on 2 m DTM (digital terrain model)

[2] East Pye Solar Pre-Examination Newsletter - April 2026

[3] BGS Hydrogeological Maps Northern East Anglia Map 4

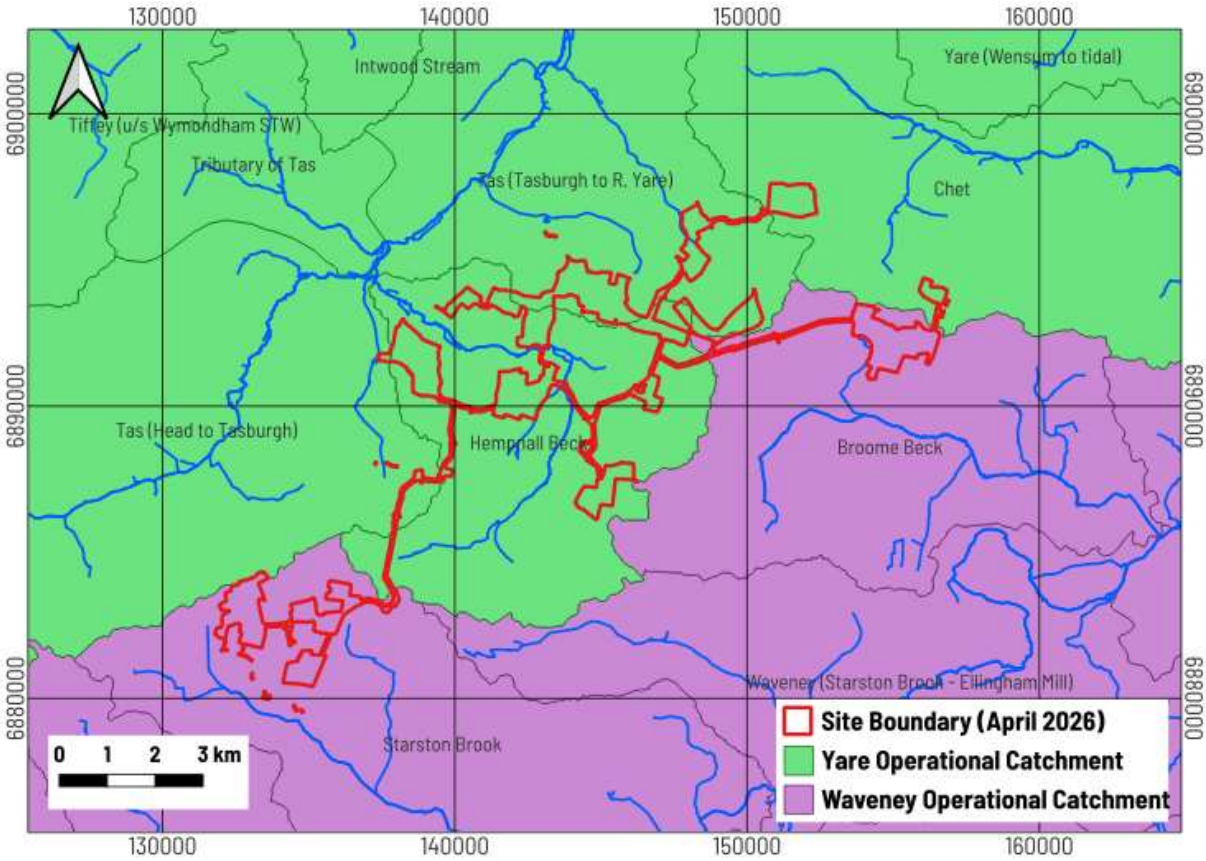


Figure 2-3 Water Bodies Catchments

2.4 Bedrock and Superficial Geology

The bedrock geology under the proposed site plan can be seen in Figure 2-4 below. The Site area sits largely upon the Crag Group bedrock, which is defined as: Sands, gravels, silts and clays. The sands are characteristically dark green from glauconite but weather to bright orange with haematite 'iron pans'. The gravels in the lower part of the group are almost entirely composed of flint[4].

The White Chalk Subgroup sits unconformably below the Crag group, and below the site on the eastern side. This is defined as: Chalk with flints. With discrete marl seams, nodular chalk, sponge-rich and flint seams throughout.

[4] The BGS Lexicon of Named Rock Units, Crag Group

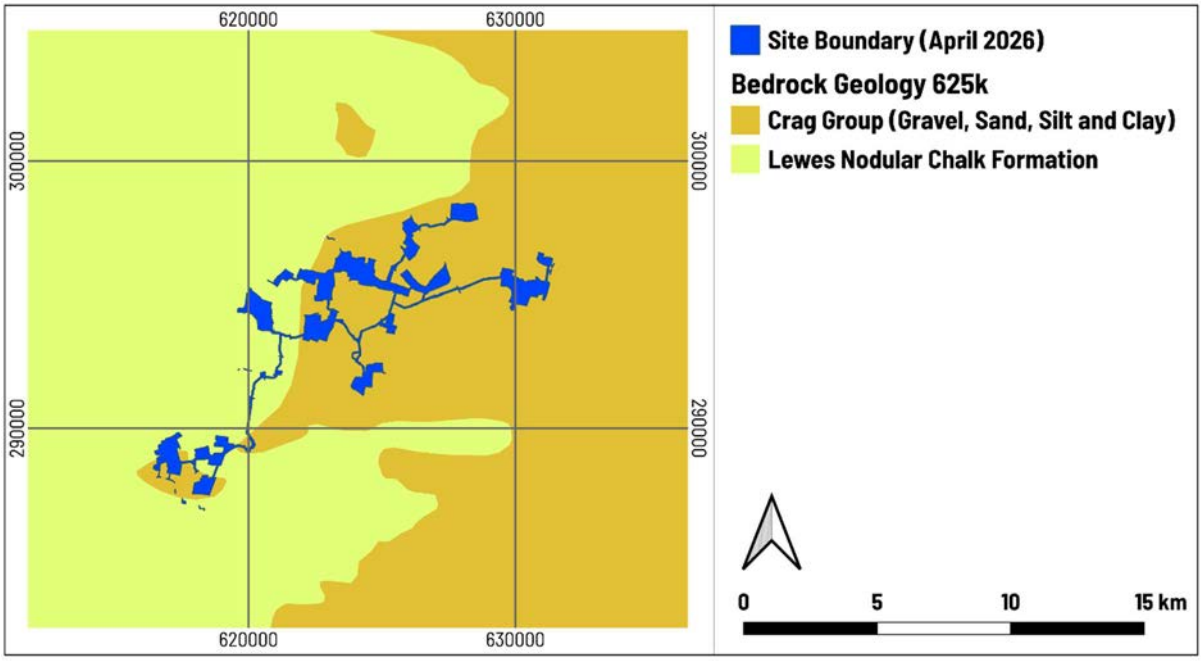


Figure 2-4 Bedrock Geology 625k

Contains British Geological Survey materials © UKRI [2026].

Figure 2-5 below shows the local superficial geology in 50k resolution. This indicates that the site is broadly underlain by Diamicton Till (specifically The Lowestoft Formation, a chalky Till), this is defined as: unsorted and unstratified drift, generally overconsolidated, deposited directly by and underneath a glacier without subsequent reworking by water from the glacier. It consists of a heterogenous mixture of clay, sand, gravel, and boulders varying widely in size and shape (Diamicton). A band of Leet Hill Sand And Gravel Member lies in the valley of the Hempnall Beck, through the central Site, which is overlain in the central valley by Alluvium, some Happisburgh Glacigenic Formation And Lowestoft Formation, Head and Peat.

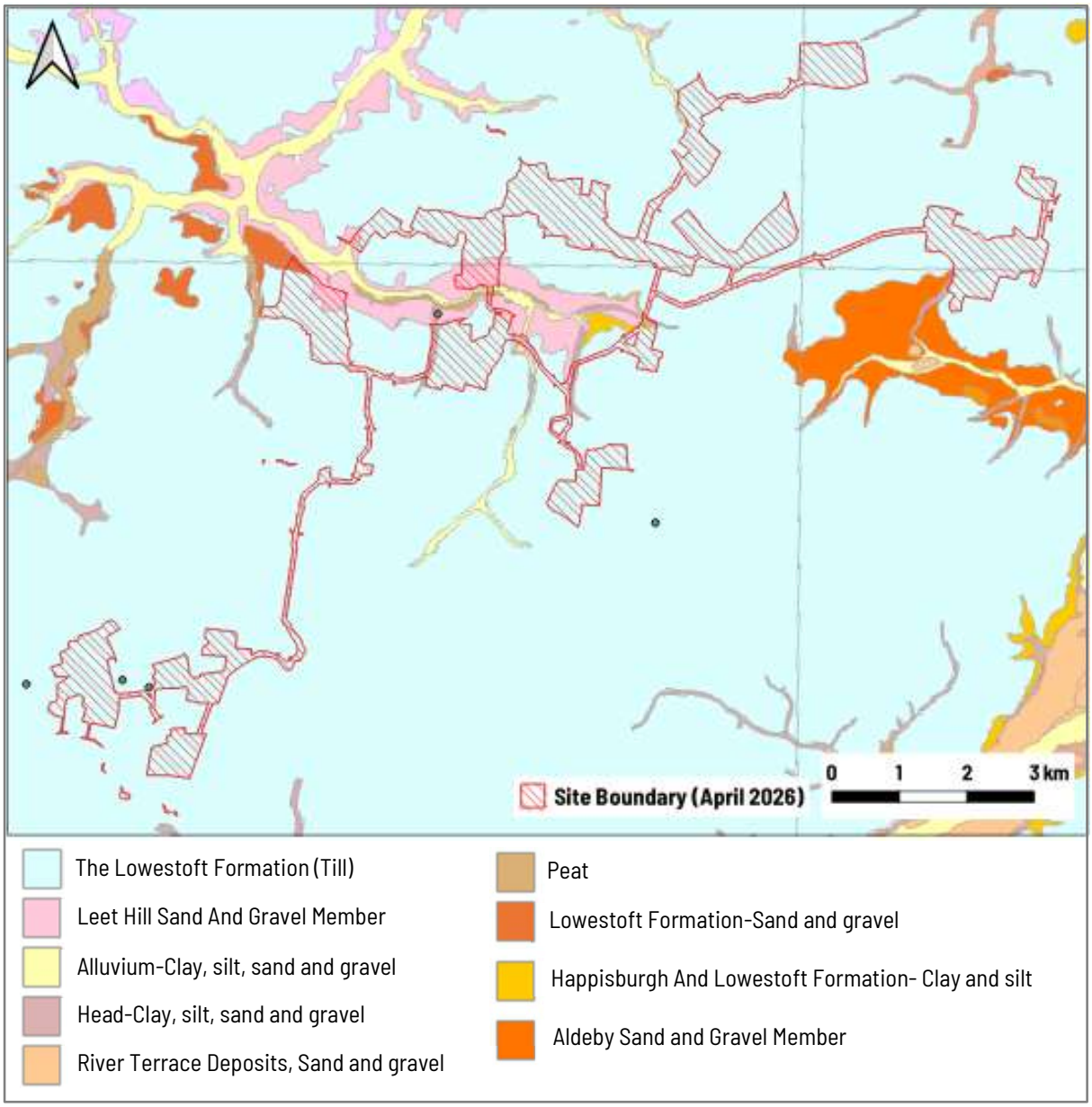


Figure 2-5 Superficial Geology 50k
Contains British Geological Survey materials © UKRI [2026].

2.5 Hydrogeology

The Crag Group and underlying White Chalk are classed as principal aquifers. The Till underlaying the site is classed as a Secondary (undifferentiated) aquifer and the Sand and Gravel deposits as Secondary A. The groundwater vulnerability is generally classed as medium to medium-high[5].

2.5.1 Private water supplies (PrWS)

The Applicant has not provided the full list of PrWS obtained from the Local Authority and states the reason for this as being due to the Local Authority's Data Protection requirements. HFCL approached the Local Authority to obtain the location of PrWS, as shown in Figure 2-6. It can be seen that there are PrWS abstractions within the site itself, and many others close to the proposed development.

[5] Groundwater Vulnerability Maps (2017) on MAGIC

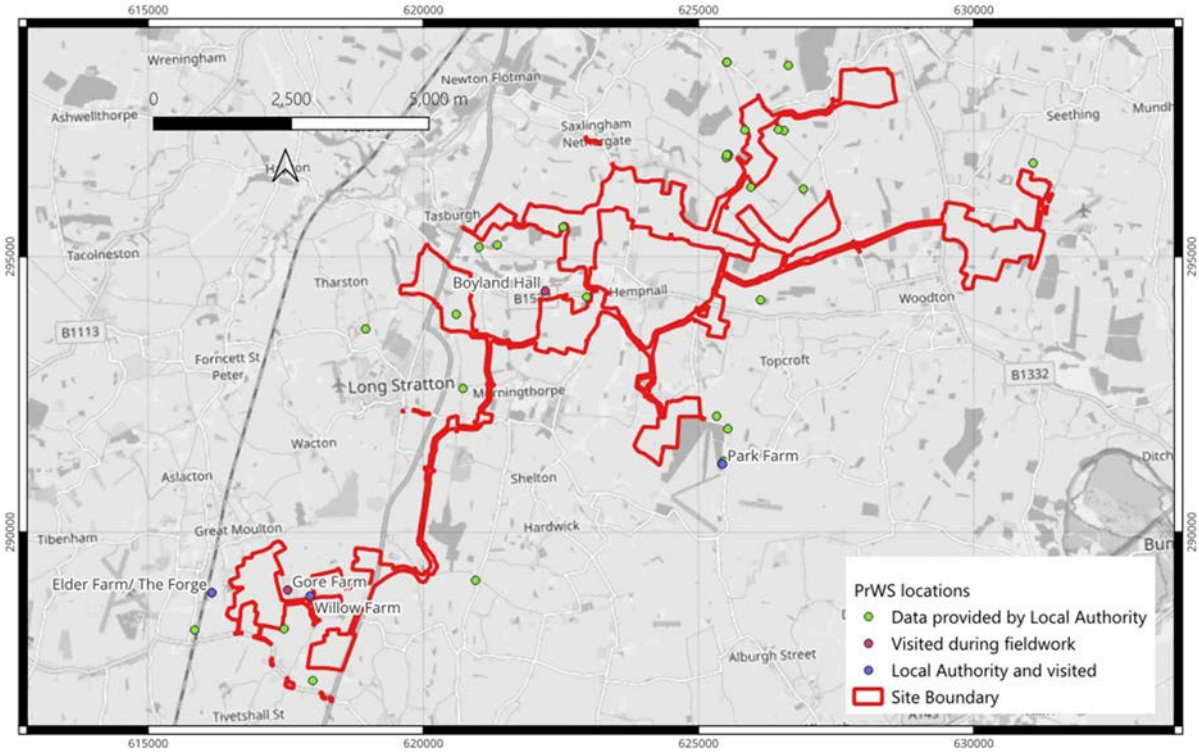


Figure 2-6 Private water supply (PrWS) locations provided by South Norfolk District Council and observed during fieldwork

During the site visit, a small selection of businesses and residences were visited, to verify the local conditions and confirm the location of a subset of Private Water Supplies. These are mapped along with all BGS recorded boreholes in Figure 2-7 below. A summary of the properties visited is given in Table 2.1

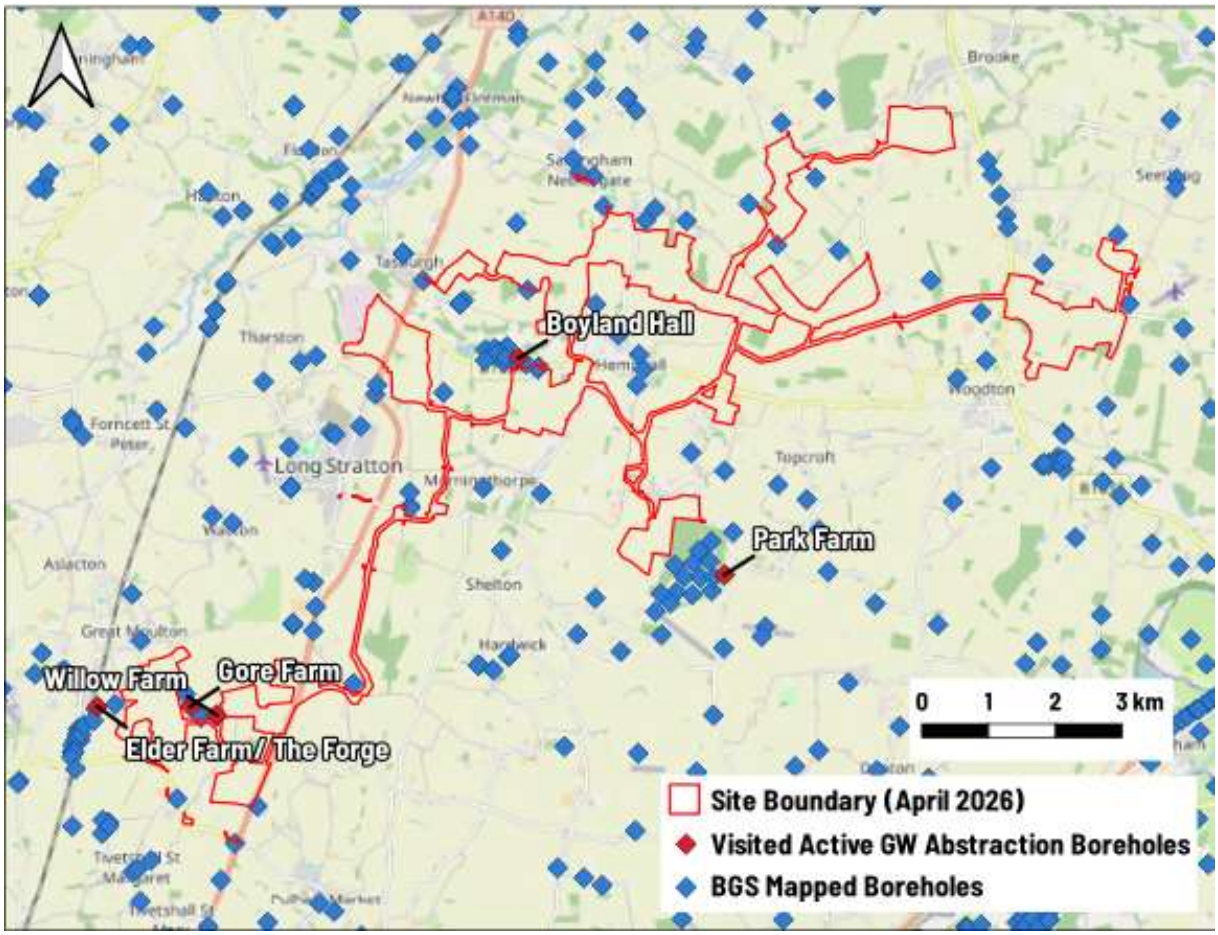


Figure 2-7 Local Borehole Records

Table 2.1 Private water supplies visited during site visit

Name	Location (x,y)	Sit visit notes	Applicant's conclusions
Boyland Hall	622222, 294386	Active groundwater pumping borehole. Resident's only water supply.	Assumed to be represented by BGS logs TM29SW13 and TM29SW14. Boyland Hall and all outbuildings now demolished. Assume disused.
Elder Farm/ The Forge	616144, 288896	Active groundwater pumping borehole, under manhole cover. Resident's only water supply.	BGS records indicate this borehole is lined into the chalk and (in 1980) was fitted with a submersible pump. Assume active.
Gore Farm	617540, 288957	Active groundwater pumping borehole.	EA permitted abstraction. Allows the abstraction groundwater from a borehole, for the purposes of "General Farming and Domestic". Assumed to have drawn water from chalk, based on geology of nearby TM18NE34. Assume active.

Name	Location (x,y)	Sit visit notes	Applicant's conclusions
Park Farm	625451, 291290	Active groundwater pumping well, under manhole cover. Resident's only water supply.	Outside of 250m buffer so not discussed by Applicant.
Willow Farm	617937, 288850	Active groundwater pumping borehole, under manhole cover. Resident's only water supply.	BGS Water Well Record. Borehole encounters chalk at 22.5m bgl. Water struck at 45.1m bgl. Lined to 44.6m bgl. Assumed to draw water from chalk. Visit record dated 30/11/1950 states "in use for farm, 500 [gallons per day]. Takes over an hour to pump. Petrol engine. Bore inaccessible for measurement". Borehole assumed to still be in use as an active PWS record is provided.

It can be seen that there are several locations where a private groundwater supply is the only source of water to a residence; indeed it is likely that a large proportion if not all private water supplies are the only water supply to a residence. It is also evident from speaking with local residents that some of these supplies are from shallow groundwater sources. Assumptions made by the Applicant can be seen to be inaccurate in the case of the Boyland Hall supply. It is considered likely that other PrWS will have been omitted from assessment due to the Applicant's lack of lack of ground truthing and lack of cross-checking with address database.

2.5.2 Environmentally Sensitive Sites

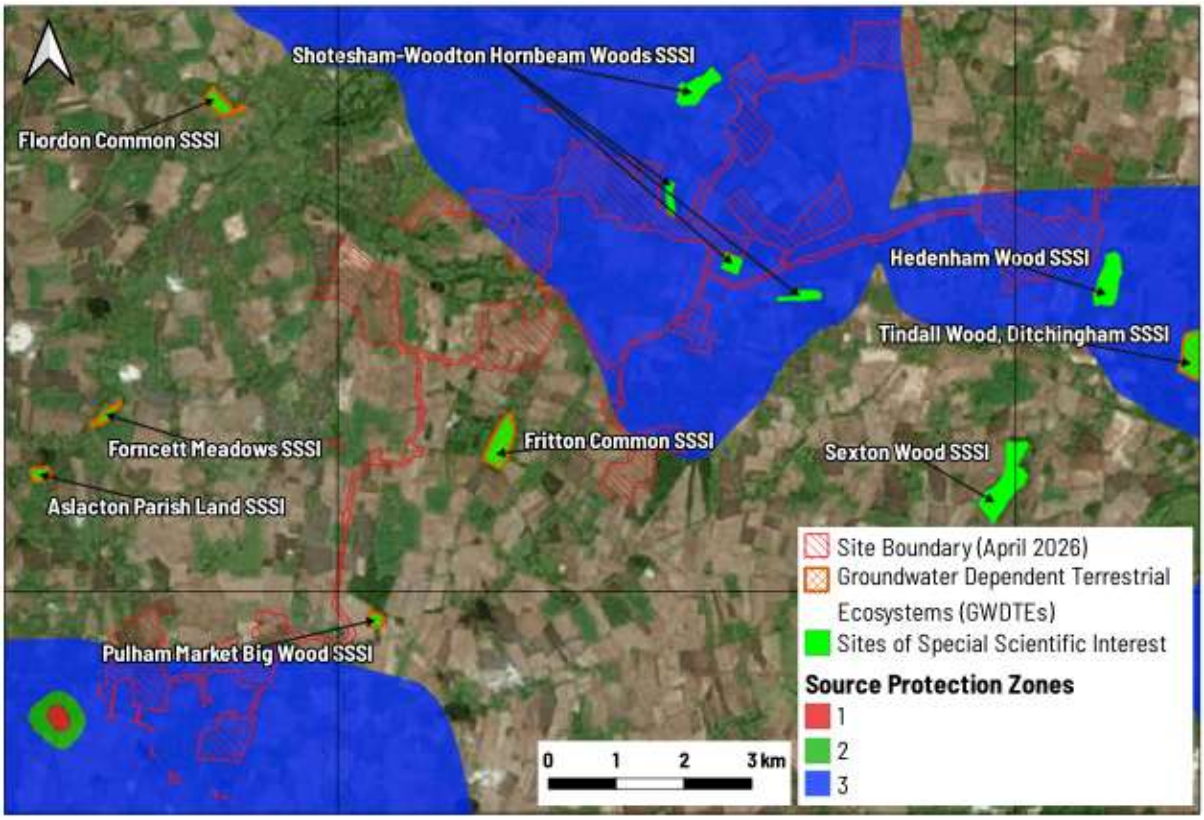


Figure 2-8 Environmentally Sensitive Sites

A variety of environmentally sensitive sites lie close to The Site and can be seen in Figure 2-8 above. Shotesham-Woodton Hornbeam Woods Site of Special Scientific Interest (SSSI) includes land parcels adjacent to The Site boundary towards the top of The Site. Fritton Common SSSI sits with The Site to the west, north and east, Hedenham Wood SSSI sits close to the eastern border and Pulham Market Big Wood SSSI is close to the connecting corridor southwards of the site. Other SSSIs within approximately 5 km include Flordon Common, Forncett Meadows, Aslacton Parish Land, Tindall Wood (Ditchingham) and Sexton Wood.

Flordon Common, Forncett Meadows, Aslacton Parish Land, Pulham Market Big Wood, Fritton Common and Tindall Wood Ditchingham are also designated Groundwater Dependent Terrestrial Ecosystems (GWDTEs), making them sensitive to changes in groundwater level and quality.

Large areas of the Site fall within Source Protection Zones (SPZ) specifically zone 3 (This is the area around a groundwater supply source within which all the groundwater ends up at the abstraction point). A SPZ1 and SPZ2 are present 700 m and 350 m from the southwestern border but do not overlap the site.

3 ES REVIEW

3.1 ES Chapter 9 Water Resources and Chapter 16 Ground Conditions

Hydrology and surface water is the subject of Chapter 9. Chapter 9 also assesses the potential impact on water resources. Hydrogeology forms part of the subject of Chapter 16. The text within the ES acknowledges the interplay between the two Chapters, but the splitting of hydrology and hydrogeology does appear to have led to some inconsistencies and omissions in the overall ES, as discussed below.

Due to the overlapping subject areas, both Chapters are commented on in tandem below, so that the topics of hydrology and hydrogeology can be reviewed in a cohesive manner.

3.1.1 Assessment Methodology

The method of assessment is set out by the Applicant in Sections 9.5 and 16.5 of the ES. That set out in Section 9.5 has several elements that require further clarification:

1. Table 9.3 sets out the criteria for sensitivity of receptor. Within the descriptions of each sensitivity level, distance from the scheme boundary is used as a qualifying factor in receptor sensitivity. There are two issues with this:
    a. The sensitivity of a receptor is intrinsic to that receptor and its ability to withstand or recover from change. It should not be related to distance from the scheme. The distance from (or connectivity to) the scheme controls how likely an impact on a receptor is, not its sensitivity to that impact.
    b. Notwithstanding the above point, distance from the scheme is not necessarily a reliable indicator of the degree of connectivity. It is the degree of connectivity that will control how likely a receptor may be impacted, and distance from the scheme is only one of several controls on connectivity.

    There is then inconsistency in how distance from the scheme is used to qualify the sensitivity of Private Water Supplies (PWS):
    - Table 9.3 uses distance criteria of <50 m Very High, 50 – 250 m High, 250 – 500 m Medium, 500 – 1,000 m Low and >1,000 m Negligible.
    - Table 9.4 uses <1 km Very High, 1 – 3 km High, and 3 – 5 km Medium
2. The water resources assessment is inconsistent with the Anglian District River Basin Management Plan (RBMP) (which sets the required water quality status and objectives under the Water Framework Directive Regulations (2015)). In Table 9.5 the threshold defining a High magnitude of change (the largest magnitude) requires that a detrimental impact on water quality needs to be sufficient to have caused two steps down in the water body status (e.g. from High to Medium). The objectives set by the RBMP however are to; prevent deterioration of the status of surface water and groundwater; to achieve objectives and standards for protected areas, and; to aim to achieve 'good status' for all waterbodies. The definition of a High magnitude of change should match these objectives.
3. The definition of magnitude of change for water resources assessment is inconsistent with those set out in Chapter 8 for the same receptors. In Chapter 9, the entire loss of a legally protected wildlife site is required to qualify as a High magnitude of change. Chapter 8 describes a High magnitude of change as being "a permanent or long-term effect on an Important Ecological Feature (which is defined elsewhere in the document as including legally protected sites), which may result in severe damage to key characteristics and implications for the integrity of the receptor or its conservation status". This latter definition accords with guidelines provided by the Chartered Institute of Ecology and Environmental Management (CIEEM). The definition as set out in Chapter 9 is inconsistent with this guidance. It does not align with the aims of the Wildlife and Countryside Act

(W&CA) 1981 nor does it adhere to the requirements of the Conservation of Habitats and Species Regulations (Habitats Regulations) 2017, both of which protect the integrity and status of protected wildlife sites, as well as their existence.

4. The matrix used to ascribe the relationship between magnitude of effect, sensitivity of receptor and significance of effect in Chapter 9 is not consistent with that in Chapter 16. Whilst it is accepted practice in EIA that each subject area may have differing mechanisms for defining significance of effect, the commonalities between these two subject areas makes it unhelpful. This is of particular importance given that surface water and groundwater are split between the two Chapters.
   Indeed, the matrix used in Chapter 9 is unsatisfactory in that it jumps two classes of significance of effect (Major to Minor) in response to a single step in magnitude of impact (Medium to Low). Negligible significance of change results from a combination of higher sensitivity and magnitude classes (e.g. low x low = negligible, whereas low x low = minor would be more appropriate). Minor/ Negligible is also inappropriately used as a product of medium x low. This inconsistency and inappropriateness in the significance of effect matrix in Chapter 9 is raised in the Environment Agency's representation. The same issues are not present in the equivalent matrix in Chapter 16.
5. The magnitude of impact categories are not consistent between Chapter 9 and Chapter 16. Chapter 9 uses four categories of magnitude; High, Medium, Low and Negligible. Chapter 16 uses five categories; Large, Medium, Small, Very Small and Negligible. It is difficult to correlate between the two chapters where apparent overlap occurs (e.g. for the magnitude of change associated with water quality in surface water features, which is defined in terms of Environmental Quality Standards in Chapter 16, but is described in terms of deterioration between WFD classes in Chapter 9).

3.1.2 Scope

A description of the water body catchments (as defined by the Environment Agency under WFD) that the scheme is situated within is provided in Chapter 9 and in Technical Appendix 9.2 (Water Framework Directive Assessment). There are six such water body catchments and a groundwater body.

The Applicant screens three of the water body catchments out of the WFD and ES process on the basis that there are no main rivers or watercourses within the footprint of the scheme. In each case, ditches have been identified within the scheme. These ditches are connected directly to water bodies. The proposed construction programme will include considerable disturbance of the ground, with the potential for mobilising silt and other pollutants (fuels, oils, foul effluent from works compounds, plant & equipment, for example). The screening out of these water bodies is not appropriate.

The groundwater of the Broadland Rivers Chalk and Crag Water Body has been scoped out of the WFD assessment by the Applicant. The rationale provided is that the proposed scheme only covers a relatively small proportion of the total catchment. Given the importance of this aquifer to both private and public water supply in the region (many of which are extremely close to the scheme), this is inappropriate.

The Water Resources Assessment (Technical Appendix 9.3) appears to take no account of the water required by the project during construction, other than that consumed by the associated welfare units. Water will also be required for concrete batching, dust suppression, cleaning of plant & equipment for example.

3.1.3 Baseline

3.1.3.1 Private Water Supplies (PWS)

The methodology used by the Applicant to ensure that all PWSs have been identified and assessed is not presented. Three sources have been described (Local Authority records, BGS database records and Environment Agency permit records). It is typical that, even in combination, such sources do not enable identification of all of PWS. Cross-checking with an address database and mains water supply records is required such that further investigation can be made into those addresses that do not have an identified PWS, nor are connected to the mains network. Such investigation includes ground-truthing where details of the abstraction are not available.

Unless these steps have been taken, the PWS baseline has been insufficiently characterised, and potentially sensitive receptors remain unidentified.

This is important, as the Water Resources Assessment characterises the known PWS supplies as predominantly drawing from the chalk, which is overlain by the glacial till of the Lowestoft Formation. Limited ground-truthing undertaken by HFCL has proven that PWS abstractions from the glacial till at shallow depths are not unusual.

HFCL have obtained the PWS database from the Local Authority and it has been received in the form of grid reference locations only. Of these, three were visited during the HFCL site survey, in addition to a further EA licenced supply and, critically, a supply that did not appear on the Local Authority list that remains active but was assumed inactive by the Applicant (Boyland Hall). The HFCL site survey was very limited and intended as a snapshot of site conditions only. It is therefore possible (indeed probable) that other PrWS have been omitted from the Applicant's assessment. A programme of cross-checking with address database and subsequent ground truthing is required to ensure that all PrWS are identified and appropriately assessed.

3.1.3.2 GWDTEs

The Environment Agency has identified GWDTEs within SSSIs that have not been identified by the Applicant.

3.1.3.3 Aquifer designation

Table 16.7 characterises the bedrock aquifers as Secondary A Aquifers (incorrectly). Following sections of the Chapter then list it (correctly) as a Principal Aquifer. The Chalk and Crag Group are a Principal Aquifer, and of strategic importance in supplying water to the residents, agriculture and industry of East Anglia. Table 16.12 is confused as to whether the SPZs are protective of groundwater abstractions from the shallow superficial deposits or deeper bedrock beneath. This should be clarified.

3.1.3.4 SPZs

As highlighted by the Environment Agency in their representation, Chapter 9 of the ES has not identified the presence of Zone I of a Source Protection Zone (SPZ) which lies within the study area.

Chapter 9 also does not properly represent the extent of all of the SPZs present beneath the scheme. It simply refers to the northern part of the scheme being within an SPZ. In fact of the entire scheme, only Sites 2C, 4A, 4B, 5A and 7A are outside of an SPZ. The majority of the scheme lies within SPZ limits.

3.1.3.5 Conceptual model

The Applicant does not provide or define the hydrogeological conceptual model anywhere in the ES documentation. The Water Resources Assessment focusses purely on potable and non-potable water resources, with no discussion of the overall conceptual model. The baseline section of Chapter 9 of the ES makes no reference to the current hydrogeological conditions at all. Chapter 16 provides a description of the EA aquifer designations, but provides no description of the hydrogeological conditions. Thus the assessment of wider hydrological and hydrogeological impacts is not supported by a sufficiently defined baseline.

Of particular note is the lack of due consideration of the hydrogeological relationship between the chalk and Crag Group Principal Aquifer at depth and the overlying Lowestoft Till Formation. The BGS have published a paper on the importance of this relationship when assessing the degree to which changes made at the ground surface may impact the Principal Aquifer at depth. This concludes that;

- Recharge to the chalk aquifer through the till is between 4.5% and 20% of effective rainfall (i.e. not insignificant);
- Overland flow is rare, consistent with a relatively permeable weathered till horizon and, where present, cover sand at shallow depths;
- The weathered till of the Lowestoft Formation has hydraulic conductivities typically between 10^{-6} m/s and 10^{-8} m/s, but can be as high as 10^{-5}m/s. Groundwater movement and storage can therefore be expected in some locations in weathered horizons.

The Lowestoft Formation is incorrectly characterised as impermeable in the Ground Conditions Desk Study (e.g. Section 2.4.10). The research undertaken by the BGS indicates that this the reality is more complex than this. The upper, weathered horizons in the formation can be relatively permeable, and are known to support PWSs in some locations. Sand and gravel horizons and lenses are described by the BGS, and the Formation is designated as a Secondary (Undifferentiated) Aquifer by the EA. The degree of permeability in the shallow till is also reflected in the medium groundwater vulnerability ascribed to the Formation by the EA, and the presence of GWDTEs within the area of glacial till coverage.

3.1.4 Assessment

3.1.4.1 Assessment of effects

In both Chapters, effects are combined in the assessment, preventing the interrogation of the EIA at a receptor-by-receptor level.

Impact on the hydrogeology and the aquifers beneath the scheme are assessed in Chapter 16. However, the construction phase effects included within the assessment are only those associated with the potential for the scheme to mobilise contamination that may already be present within the areas of brownfield land present within the scheme footprint. No assessment has been made of the potential for the development itself to cause impact to the aquifers (through silt run-off, leaks, spills etc.).

The assessment of effects on water resources is predicated on the water balance set out in the Water Resources Assessment (Technical Appendix 9.3). The lack of available potable or non-potable water in the catchment is acknowledged by the applicant, rendering it impossible for the Applicant to be provided with water by means of supply (from Anglian Water Services) or abstraction.

The solution to this is set out in the WRA as being twofold;

- Import of water to site by road tanker, and;
- Rainwater harvesting.

No information is provided on the origin of the tankered, imported water. Given much of East Anglia is under similar water stress, this is important to define in order that the Applicant can substantiate the lack of significant impact stated within the ES.

Rainwater harvesting for use by the development is presented as water-neutral (i.e. 100% non-consumptive). This will not be the case; for example, there will be water that ends up in foul effluent exported from site, water lost through evapotranspiration during use, etc. This consumptive element could be significant in both construction and operational phase, which in turn reduces the volume of water infiltrating to ground.

This is important, because no account is made of this effect in Chapter 9 or Chapter 16 (with respect to potential impact on PWSs, particularly those which abstract from the shallow glacial till), nor in Chapter 8 (with respect to potential impact on ecological features and habitat creation/ Habitat Management Plan).

3.1.4.2 GWDTE assessment

No assessment of the potential linkage(s) between the scheme and GWDTEs has been provided by the Applicant. GWDTEs are not fully assessed and the hydrogeological conceptual model has not been properly characterised in this regard.

3.1.4.3 Water quality

There is confusion in the assessment of impact to water quality. Chapter 9 uses WFD classes as a metric for measuring magnitude of effect, whereas Chapter 16 uses EQS. Magnitude of change has 4 classes in Chapter 9, 5 classes in Chapter 16.

No hydrogeological conceptual model is provided, and hence assessment of the interaction of the scheme with hydrology and hydrogeology receptors has not been informed by a full understanding of the hydrogeological conditions.

Insufficient detail is provided on; the baseline water quality; the relative position of the scheme in each Water Body catchment, and; the possible impact of the development on these water bodies. This is of particular importance given the scale of the development and its location at the headwater of some catchments.

3.2 Technical Appendices

Where elements of the Technical Appendices are relevant to the discussion of ES content and process, these have been discussed in Section 3.1 above. Additional observations on the individual Appendices are made below, where considered salient.

3.2.1 Technical Appendix 9.1 FRA and Outline Surface Water Drainage Strategy

Paragraph 9.10.16 identified areas at surface water flood risk within and in the area of the 400kV substation and National Grid Substation in Sub-Site 1B. The same paragraph states that "an appropriate solution will be considered at the detailed design stage for the conveyance of surface water exceedance flows from the fields upstream of these areas". It is critically important that water arising from surface water flooding is not managed by the same system as will deliver the containment of firewater, as this could lead to the overwhelming of the containment system in the event that a fire and stormwater event coincide.

In discussing mitigation measures, paragraph 9.11.4 states that "the BESS may be split into 'compartments' of battery units, each with their own associated lined aggregate sub-base area and

separated by lengths of access track. This would aid in the isolating and testing of surface water runoff, and remediation of affected areas following a fire incident". The use of qualifying words "may" and "would" makes it impossible to determine whether this is planned mitigation or not.

3.2.2 Technical Appendix 9.2 WFD Assessment

As discussed in Section 3.1.2, three of the water body catchments and the groundwater body are scoped out of the WFD assessment.

Given that there are water features within the scheme that drain to these water bodies, this is not appropriate.

Similarly, whilst the groundwater of the Broadland Rivers Chalk and Crag Water Body has been scoped out of the WFD assessment by the Applicant, this is purely on the basis that the scheme covers a relatively small proportion of the total catchment. The decision to screen in or out should be made on the likely impact the scheme may have on any part of the groundwater body, not aggregated across its entire catchment. To do otherwise does not give sufficient attention to the potential for deterioration of water quality in groundwater baseflow or in locally important groundwater resources, for example.

3.2.3 Technical Appendix 9.3 Water Resource Assessment

There is no assessment made of water quality impacts within this document. This is addressed at high level only in Chapter 9 and Chapter 16.

No allowance has been made in the WRA water balance assessment for water required in construction processes. Water will be required for processes including concrete batching, dust suppression, cleaning of plant & equipment etc. and this has not been included in the water balance.

There is no confirmation as to where the imported tankered water will be coming from. Other catchments across East Anglia are under similar levels of water stress, and it must be ensured that the problem is not displaced to impact another, similarly stressed catchment.

If rainfall harvesting is used, then this will also need to be considered in the water balance, as some of that use will be consumptive (e.g. that which ends up as foul drainage to be tankered away), and so overall infiltration will be reduced, hence recharge to aquifer will be reduced.

Rainfall capture from the new panels will decrease infiltration to ground, and it is not clear whether this reduction in infiltration been taken account of in the assessment of habitats and ecology in Chapter 8 and in the Habitat Management Plan.

The figures presented within the WRA do not appear to tally correctly. For example, Section 2.1.8 describes 278 people on site during construction, requiring 0.1m^3 each (a daily demand of 27.8m^3). However, the daily demand stated in Section 2.1.6 is 31.13m^3. Section 2.1.9 states that between 0.04m^3 and 0.06m^3 (40 to 60%) of the required water is non potable, but the daily non-potable construction phase demand stated in Section 2.1.6 is 55.38% and it is not clear how this has been arrived at.

3.2.4 Technical Appendix 16.1 Phase 1 Ground Conditions Assessment

Table 3-10 of the document sets out the details of each identified PWS within 3 km of the scheme. It ascribes a target stratum for each borehole, either based on direct evidence (i.e. historical borehole log) or by extrapolation from other sources. In this process, the Applicant has assumed that the presence of Lowestoft Formation (as indicated by nearby exploratory hole records) precludes the possibility that this is the source of water being abstracted. In other cases the

Applicant states that the thinning of the Lowestoft Formation is also evidence to suggest it is not being used as a source. These two assumptions appear to be confused and inconsistent.

It is known that some PWS in the study area abstract from the Lowestoft Formation, so these assumptions may be unsound. Indeed, for PWS record TM29NW25, the Applicant sets out how the Lowestoft Formation supports this abstraction, confirming that the till can indeed support PWSs.

The document discusses the possible need for piled foundations, and that these may present preferential vertical pathways for pollution migration. It then assesses this to be low risk, due to the absence of brownfield land sources where piled structures may be required. Such assessment takes no account of the source potential represented by the scheme itself, both during the construction phase (fuels, oils etc.) and operational phase (BESS firewater, etc.).

3.2.5 Technical Appendix 16.2 Mineral Resource Assessment Desk Study

No detailed comments are provided on this document and it has not been reviewed in detail.

4 SUMMARY OF KEY COMMENTS

The following table provides a summary of the key observations and comments arising from this review, and provides a note on whether the assessment has met the required guidance, including consideration as to whether Regulation 20 of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 applies (i.e. further information is required from the Applicant).

Table 4.1 Summary of key comments

Ref.	Comment/ Observation	Note on adherence to guidance/ Regulation 20 consideration
1	The definition of effect differs between Chapter 9 (within which hydrology is primarily addressed) and Chapter 16 (within which hydrogeology is primarily addressed). This lack of consistency is significant given the aspects of connectivity and commonality between the two chapters.	Does not follow guidance (e.g. EU 2017[6]) Requires further information under Regulation 20
2	The definition of significance of effect in Chapter 9 is not precautionary enough in its treatment of protected wildlife sites. It is not consistent with Chapter 8 in this regard.	Does not meet requirements of W&CA 1981 or Habs Regs 2017. Requires further information under Regulation 20
3	The definition of significance of effect in Chapter 9 is not precautionary enough in its treatment of water bodies, and it is not consistent with Chapter 16 in this regard.	Does not meet the requirements of WFD[7]. Requires further information under Regulation 20
4	Three WFD surface water bodies and one WFD groundwater body have been screened out of the EIA and WFD assessment processes, despite development being planned in the catchment, and despite the presence of water features within the scheme that connect to these water bodies. Insufficient consideration has been given to the potentially contaminative effect of the development itself.	Does not meet the requirements of WFD. Requires further information under Regulation 20
5	The assessment of impact on water resources does not include due consideration of the water that will be required during construction (for concrete batching, dust suppression etc.)	Does not follow guidance (e.g. EU 2017[8])

[6] Environmental Impact Assessment of Projects Guidance on the preparation of the Environmental Impact Assessment Report (Directive 2011/92/EU as amended by 2014/52/EU)

[7] The Water Framework Directive as transposed into UK Law by The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017

[8] Environmental Impact Assessment of Projects Guidance on the preparation of the Environmental Impact Assessment Report (Directive 2011/92/EU as amended by 2014/52/EU)

Ref.	Comment/ Observation	Note on adherence to guidance/ Regulation 20 consideration
		Requires further information under Regulation 20
6	The assessment of impact on water resources assumes that the use of rainwater captured within the scheme will be non-consumptive. This will not be the case, as water will be lost to foul effluent, increased evapo-transpiration etc. This impacts the ecological assessment in Chapter 8 and the likely efficacy of the Habitat Management Plan.	Does not meet the requirements of WFD. Requires further information under Regulation 20
7	The assessment of water resources relies on the import of water from outside the catchments in which the scheme is located. The source of this water is not identified. Given that wider East Anglia is similarly water stressed as the scheme catchments, identifying the source for this water is important to ensure that the scheme does not derogate other water users.	Does not meet the requirements of WFD. Requires further information under Regulation 20
8	The baseline provided for PrWSs relies on assumptions that are not sound; • No comparison of the PrWS records, mains water supply records and address database has been undertaken, so properties with PrWS but without records have likely not been identified. • No ground-truthing of PrWS has been undertaken • The general assumption that the Lowestoft Formation glacial till does not support PrWS is unsound.	Lack of adherence to the available guidance on assessing PrWSs (SEPA 2024a[9]). Requires further information under Regulation 20
9	The Applicant has not identified all GWDTEs within the study area. No assessment is presented of the possible connectivity between the scheme and these GWDTEs. The impacts on these sensitive receptors have therefore been omitted from the EIA.	Lack of adherence to Defra/ EA guidance on assessment of groundwater (EA/ Defra 2017[10]). and the available guidance on assessing

[9] https://www.sepa.org.uk/media/mfzpnjwb/guidance-on-assessing-the-impacts-of-developments-on-groundwater-abstractions.docx

[10] https://www.gov.uk/government/publications/groundwater-protection-technical-guidance/groundwater-protection-technical-guidance

Ref.	Comment/ Observation	Note on adherence to guidance/ Regulation 20 consideration
		GWDTEs (SEPA 2024[11]). (Hulme, 2001)[11] Requires further information under Regulation 20
10	The applicant does not present a conceptual hydrogeological model for the site. The assessment is therefore reliant on a baseline that has not been fully characterised. An example of the importance of this is the relationship between the Lowestoft Formation glacial till and underlying chalk/ crag aquifer: The applicant has assumed the till is impermeable in the majority of cases, whereas published literature indicates a more complex model than this.	Lack of adherence to Defra/ EA guidance on assessment of groundwater[12 13 14 15]. Requires further information under Regulation 20
11	The ES chapters do not provide sufficient detail on the assessment of each category of receptor, having aggregated the summary of effects across several receptors in the ES text. This makes interrogation of the assessment process impossible and does not follow EIA regulations.	Does not follow guidance (e.g. EIA Regs 2017[16]) Requires further information under Regulation 20
12	Insufficient detail is provided in the assessment on the interaction of surface water flooding with the management of firewater and run-off in the 400kV and National Grid substations in Site 1, and on the make-up of the BESS infrastructure with relation to the management of firewater. There is therefore Insufficient detail to assess the likely effectiveness of the proposed embedded mitigation.	Insufficient detail to assess the likely effectiveness of the proposed embedded mitigation. Requires further information under Regulation 20
13	The Assessment of the potential interaction of piled structures with the underlying aquifer focusses solely	Lack of adherence to Defra/ EA guidance on assessment of

[11] https://www.sepa.org.uk/media/a1yh0blq/guidance-on-assessing-the-impacts-of-developments-on-groundwater-dependent-terrestrial-ecosystems.docx

[12] L Brown, L., Hulme, P., 2001. Environment Agency Framework for Groundwater Resources: Conceptual and Numerical Modelling. Environment Agency, R&D Technical Report W214, 2001.

[13] McMahon, A., Heathcote, J., Carey, M., Erskine, A., 2001. Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface. Environment Agency, R&D Technical Report NC/99/38/2, July 2001.

[14] **LCRM**: Stage 1 risk assessment https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm/lcrm-stage-1-risk-assessment

[15] **Groundwater risk assessment** for your environmental permit https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

[16] The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 Schedule 5.

Ref.	Comment/ Observation	Note on adherence to guidance/ Regulation 20 consideration
	on the likely presence/ absence of brownfield land (as a source of contamination). The potential for the scheme itself to be a source of contamination (e.g. fuels, oils, firewater) is not assessed.	groundwater (EA/ Defra 2017[17]). Requires further information under Regulation 20
14	There is confusion in the ES document as to the designation of the bedrock aquifer and the location of SPZs.	Clarification is required from the Applicant.
15	It is not clear how the figures used in the water balance within the Water Resources Assessment have been arrived at.	Clarification is required from the Applicant.

[17] https://www.gov.uk/government/publications/groundwater-protection-technical-guidance/groundwater-protection-technical-guidance

5 CONCLUSIONS

HFCL has reviewed the ground conditions, hydrology and hydrogeological assessments within the East Pye Solar scheme ES and associated Technical Appendices.

A series of observations and comments have been made that highlight points of deficiency in the assessment work undertaken, both in the EIA process itself and in the technical work that underpins it.

The failings identified result in the statutory requirements of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017, Wildlife and Countryside Act 1981, the Conservation of Habitats and Species Regulations 2017 and the Water Framework Directive Regulations 2015 not being met. The assessment is also not compliant with government and non - statutory guidance.

The deficiencies in the ES result in a significant lack of confidence that impacts to the water environment are properly understood or can be mitigated. The receptors that are potentially under threat from derogation or pollution of water resources include: groundwater in shallow and deep aquifers; residents relying on shallow or deep groundwater as their sole source of water supply; other groundwater and surface water users; local water courses; sensitive local aquatic ecosystems; and groundwater dependent terrestrial ecosystems. Additionally, it has not been satisfactorily demonstrated that the water use requirements of the scheme can be met in a sustainable manner.

As a result, a substantial amount of further information under Regulation 204 of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 is required before any decision can be taken regarding a Development Consent Order for this scheme.

APPENDIX A

Site walkover notes and photographs

SITE WALKOVER SURVEY

A site visit was undertaken on 17th to the 19th of June 2026 by Molly Green. The weather was hot and dry at the time of the visit.

The landscape was seen to be generally flat, with rolling hills in the northeast. Every field visited was seen to have drainage ditches, anecdotally, residents claimed all drainage ditches fill in winter. Some small streams were seen running at the time of the visit. Several properties were visited which rely fully on groundwater abstractions, with the owners all sharing worries that their supply will be effected by the scheme, and the costs of connecting to Anglian water being too expensive.

One property visited indicated a chalk stream started within his property, this also relied fully on groundwater abstractions.

Site 1

Site 1 is the location of the BESS and substations. A walkover was undertaken to ground truth the locations. The Site can be seen in **Figure** , with photos and photo locations marked on. Site 1 is in very close proximity to the village of Great Moulton.

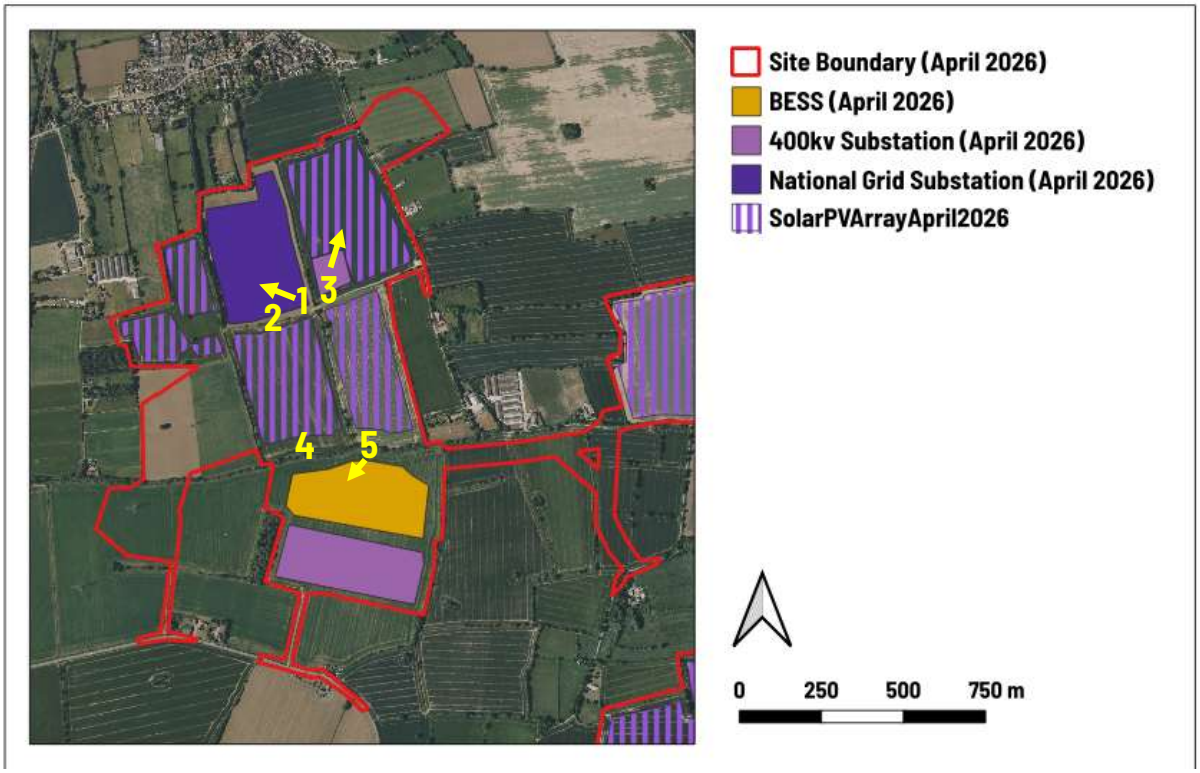
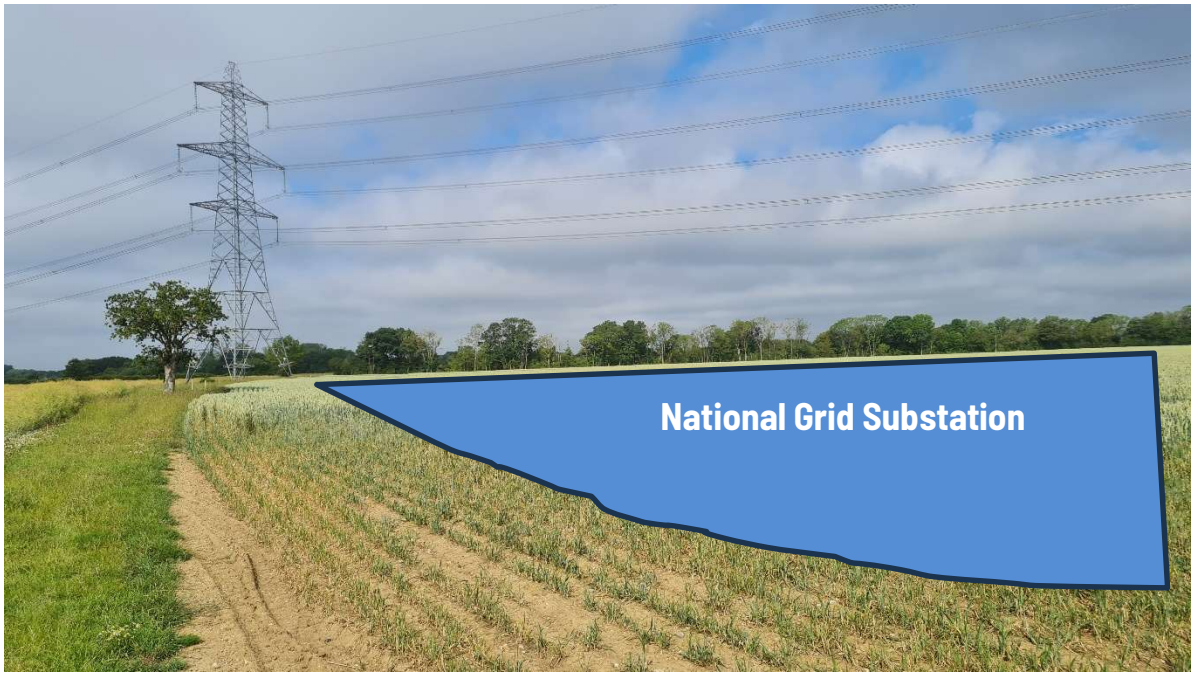
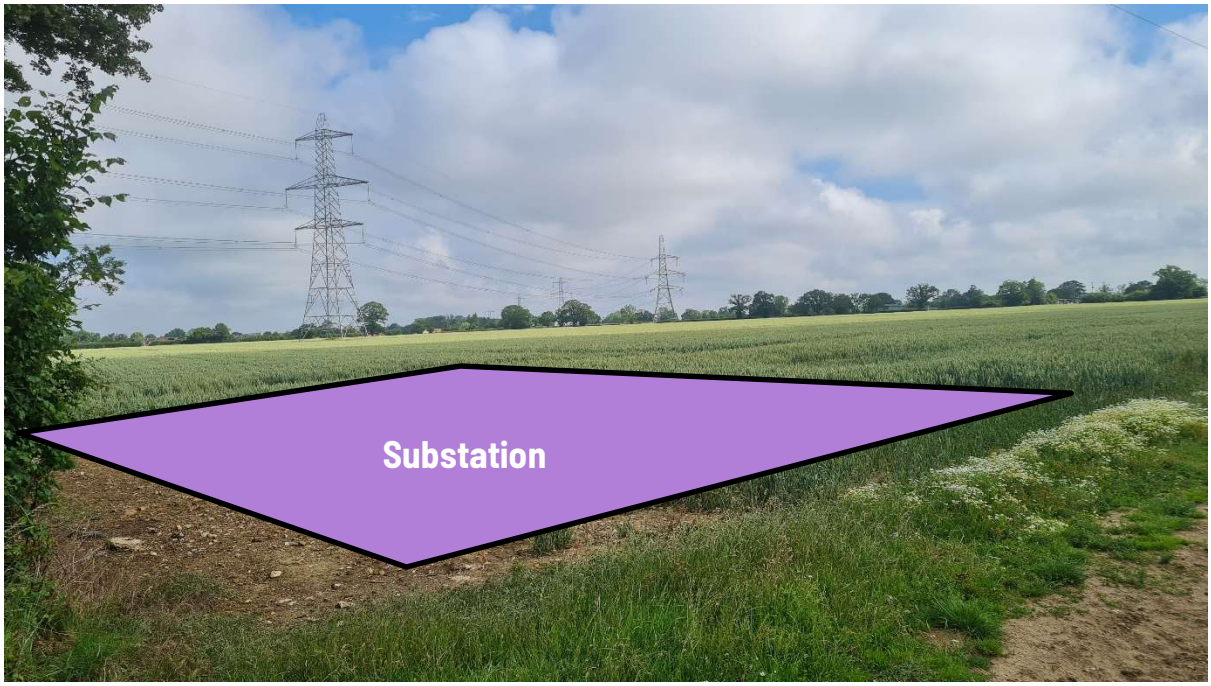


Figure A1 Site 1 Plan April 2026



Photograph 1

Photograph 2



Photograph 3

Photograph 4

Photograph 5

Site 5

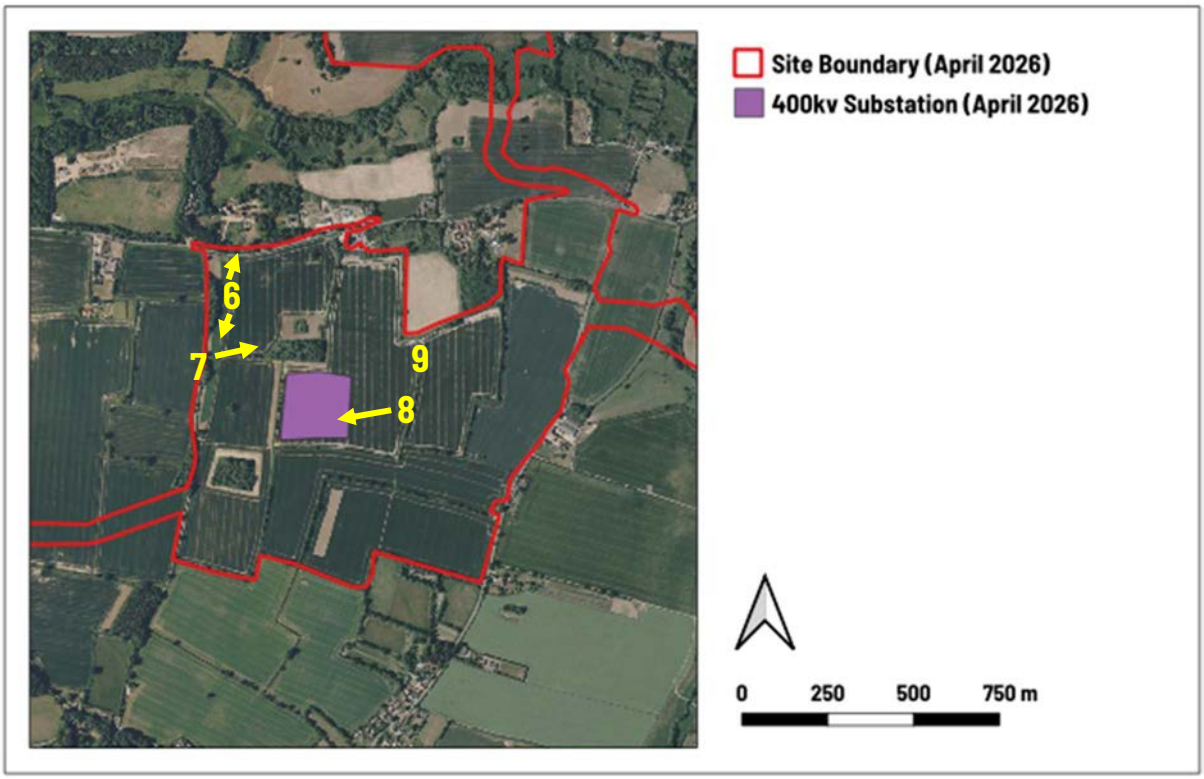


Figure A2 Site 5

Photograph 6

Photograph 7

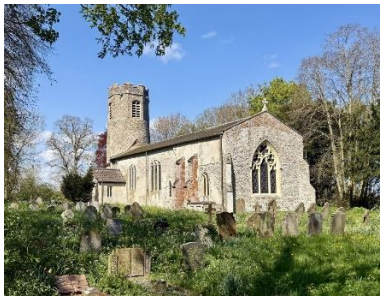
Photograph 8

Photograph 9

Heritage Impact Assessment

Proposed East Pye Solar Farm
South Norfolk

Planning Inspectorate Reference: EN0110014



[redacted]

Conservation Architect & Historic Built Environment Consultant

Tel [redacted]

September 2026

Executive Summary

This report has been prepared on behalf of Block East Pye Solar (BEPS) and considers the impact on the significance of designated heritage assets, arising from the proposed development of East Pye Solar Farm on land within South Norfolk. Site visits have been undertaken to all of those listed buildings and Conservation Areas potentially affected by the proposed development. An assessment has been made of the historic landscape character of the area and of the significance of heritage assets, including the contribution of setting and the impact of the proposed development, in accordance with good practice advice published by Historic England.

The applicant's Heritage Statement concludes that, with the exception of two designated heritage assets, the level of impact arising from the proposed development is considered to be negligible in general and causing no harm. In both cases, where the potential to cause some harm has been identified, East Pye Solar considers this to be less than substantial at the lower end of the scale through minor adverse impacts arising from changes to their setting.

It is agreed that there will be no direct impacts (other than potentially at The Old Rectory, Saxlingham Nethergate, depending upon the extent of the works) and no *'substantial harm'* to the significance of any heritage assets arising from the proposed works. However, the proposals will affect the setting of a total of 41 heritage assets, resulting in *'less than substantial harm'* to their significance, and these adverse impacts will affect a greater number than those identified in the applicant's Heritage Statement. The report also raises a number of concerns relating to the applicant's methodology for assessing setting and impact, the scale and height of the proposed solar panels which, together with the BESS, National Grid Substation (permanent infrastructure therefore affecting settings permanently) and Project Substations will introduce alien and industrial features within the rural, open and undeveloped surrounding landscape which forms the setting of heritage assets, and the potential for the proposed mitigation measures to have a harmful impact in themselves.

The report identifies the potential for the development to have **a harmful impact on a total of 41 designated heritage assets including two Grade I and three Grade II* listed, high status buildings**. It concludes that **there are considerable adverse impacts requiring great weight to be given to the conservation of designated heritage assets in the overall planning balance**, in accordance with the requirements of Sections 66 and 72 of the Planning (Listed Buildings and Conservation Areas) Act 1990, the NPPF and the Overarching National Policy Statement for Energy (EN-1).

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7.0 Conclusions

Appendix A : References

Cover photographs from top left: Grove Farmhouse, Hempnall; Church of St Catherine, Fritton; Barn Cottages, Tivetshall St Margaret; Church of St Michael & The Old Rectory, Stratton St Michael; Oldhouse Farmhouse, Brooke; Moulton Farmhouse, Great Moulton; Holly Cottage, Saxlingham Green; Seething Conservation Area; Tivetshall St Margaret and Manor Cottage, Saxlingham Nethergate.

1.0 Introduction

1.1 This report makes an assessment of the impact on the significance of heritage assets, arising from the proposed development of East Pye Solar Farm on land within South Norfolk, as set out in the application for a Development Consent Order, submitted by Island Green Power.

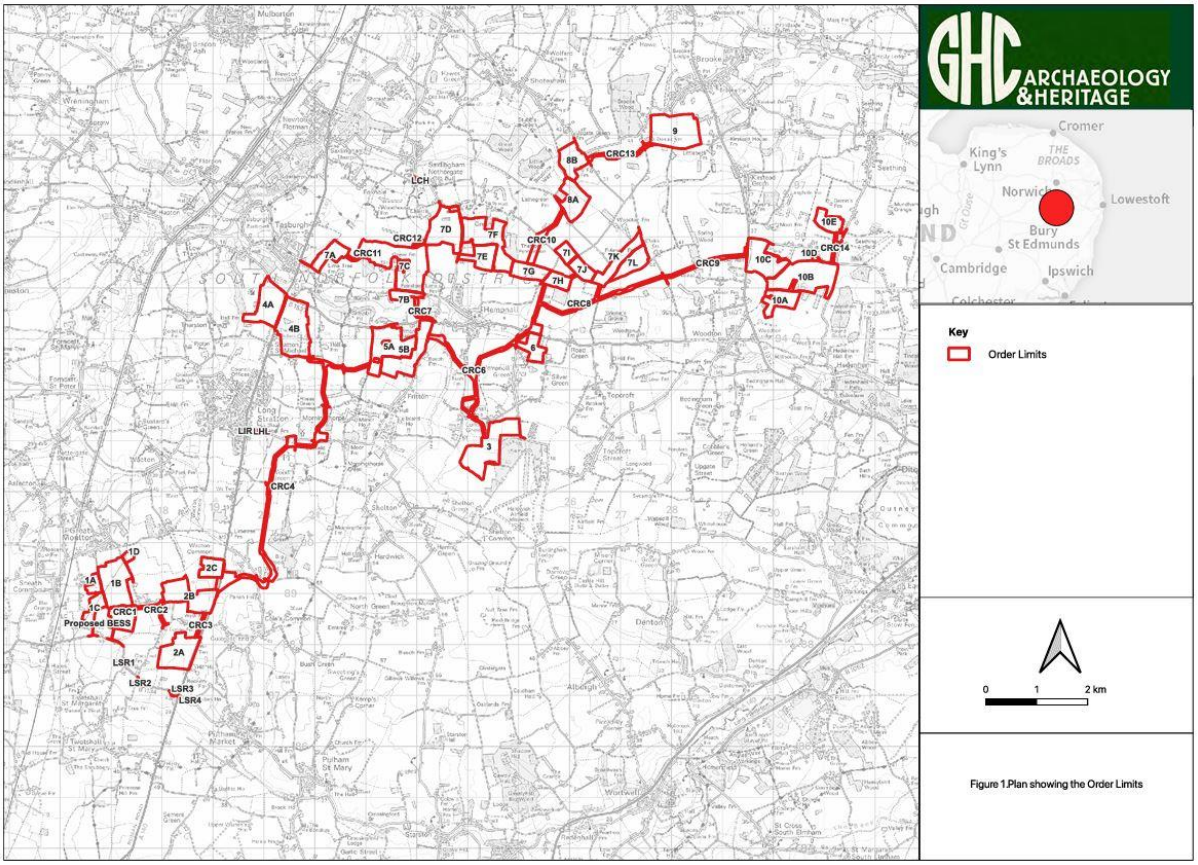
1.2 The Heritage Impact Assessment has been commissioned by Block East Pye Solar (BEPS) and prepared by [redacted] who is a member of the Royal Institute of British Architects and the Institute of Historic Building Conservation. He has over 40 years' experience in dealing with design and development affecting the historic built environment in both the public and private sectors, including acting as an expert witness on cultural heritage at several major public inquiries; design and conservation advice on applications for listed building consent and planning permission; Conservation Area designation, character appraisals and enhancement schemes; preparation of design guidance and adoption as SPDs; Heritage Statements; Statements of Significance and Heritage Impact Assessments. As the manager of the Conservation, Design and Landscape Team at South Norfolk for 18 years he was responsible for the historic built environment, listed buildings, conservation areas, design advice, trees and landscape, ecology and biodiversity. He was project manager for the South Norfolk Placemaking Guide SPD including the vernacular architecture of South Norfolk and the architectural and landscape appraisal of the District. For the past 12 years he has worked as a heritage consultant, with recent projects including a Heritage Impact Assessment for the National Grid Sea Link NSIP in East Suffolk, and preparing an architectural and landscape character appraisal for Broadland to support the South Norfolk and Broadland Design Code SPD.

1.3 This report initially considers the Environmental Statement on Cultural Heritage submitted with the application for a DCO, including the methodology used, assessment of significance and setting, identification of heritage viewpoints and the conclusions on the heritage impact of the proposals. A Heritage Impact Assessment has also been undertaken, informed by site visits to all of those heritage assets potentially affected. This has been prepared in accordance with the policies contained in the National Policy Statement for Energy (EN-1), the NPPF, and guidance in Historic England's Advice Note 12 *'Statements of Heritage Significance : Analysing Significance in Heritage Assets'* and Good Practice Advice 3 *'The Setting of Heritage Assets'.* The assessment focusses on listed buildings and Conservation Areas and the impact of proposed built development including Solar PV Arrays, Project Substations, the National Grid Substation and the Battery Energy Storage System (BESS), together with the impact of proposed road widening works to suit access requirements. The assessment does not include non-designated heritage assets or below ground archaeology or the impact of the provision of cable route corridors and other similar works.

1.4 Research has been undertaken on the history and development of the area and its context. The National Heritage List for England and the Norfolk Historic Environment Record have also been consulted along with historic maps of the area, together with archive documents and other relevant information found through internet research.

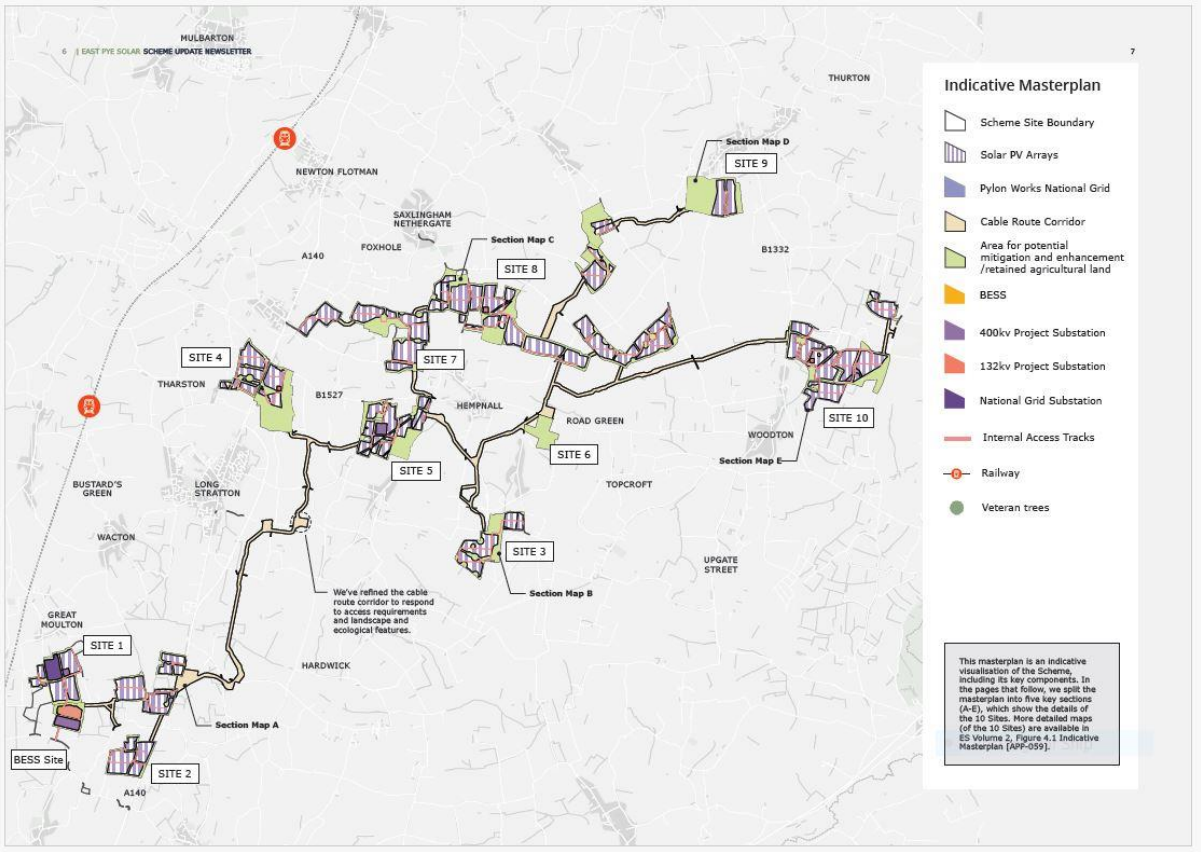
2.0 Proposed development and landscape context

2.1 The proposed development is a Nationally Significant Infrastructure Project (NSIP), being an onshore generating station in England with a capacity exceeding 100 megawatts. The scheme comprises the construction, operation and maintenance, and decommissioning of a solar photovoltaic (PV) electricity generating station including a Battery Energy Storage System (BESS), up to three 132kV Project Substations and up to three 400kV Project Substations, Grid Connection Infrastructure and a new National Grid Substation, located on 1,212.3 hectares of land (the Order Limits) within the administrative areas of South Norfolk Council and Norfolk County Council, as illustrated on the plan below. An application for a Development Consent Order (DCO) was submitted by Island Green Power on 5 March 2026 and was accepted for Examination by the Planning Inspectorate (PINS) on 2 April 2026.



01: Site Plan showing Order Limits *© GHC Archaeology & Heritage*

2.2 The scheme extends across several parishes within South Norfolk from Great Moulton in the west to Brooke, Woodton and Seething in the east and from Tivetshall in the south to Tasburgh and Saxlingham in the north. The solar panels proposed are large in scale, 4.5 metres high and are to be of the tilting (tracker) type. In addition to the provision of several solar arrays across a total of up to 10 sites, a Battery Energy Storage System (BESS) and a National Grid Substation, the scheme includes associated infrastructure – cable corridors, access routes, grid connection works and a number of substations with large transformer compounds, gantries and associated plant.



02: Indicative Masterplan, Scheme Update Newsletter April 2026 © East Pye Solar

2.3 In terms of the landscape context, all of the proposed development sites lie within the South Norfolk and High Suffolk Claylands National Character Area. The area has a slightly undulating topography comprising large areas of chalky glacial till plateau with little relief, except where incised by small rivers and streams. It has a mix of remnant mediaeval Ancient Countryside with irregular small fields and hedgerow oaks, early co-axial field patterns and large modern field sometimes devoid of hedges and trees. Large areas of woodland are relatively scarce, especially on the plateau. Views are predominantly open, occasionally being confined by hedges, hedgerow trees and scattered smaller copses that are still notable elements of the landscape. There is sometimes a feeling of exposure, although within the valleys it is possible to find quite confined landscapes with intimate views. The widespread, moderately fertile, heavy

clay chalky plateau soils support farming, predominantly for arable crops, which utilises 90 percent of the land area. This mainly ancient, long-settled landscape and above all farmland has a strong rural character, experienced through its irregular field patterns which are still recognisable over much of the area, its mediaeval churches, historic timber-framed barns and houses with colourwashed walls and thatched or tiled roofs. The settlement pattern is mixed with nucleated villages in the west and along the river valleys, intermixed with dispersed hamlets and moated farmsteads. Large, often interconnected village greens or commons with settlement around the edge, are a key feature of the area. There are few major transport routes with the area having an extensive network of narrow lanes and byroads.

2.4 Within the South Norfolk and High Suffolk Claylands National Character Area, there are a number of local Landscape Types, as set out in the South Norfolk Landscape Assessment Report. The proposed development lies within five of these areas: A1 Tas Rural River Valley; B1 Tas Tributary Farmland; B5 Chet Tributary Farmland; C2 Thurlton Tributary Farmland with Parkland and E2 Great Moulton Plateau Farmland. The key characteristics of each of these areas are as follows:

A1 Tas Rural River Valley

- Some long views within the valley but restricted external views
- Sparsely settled character with buildings of a rural vernacular appearance clustered around fording points or linear development at the upper and or lower areas of the valley sides
- Characteristic vernacular buildings including distinctive weather-boarded mill houses and Dutch gable ends
- Presence of a small number of distinctive halls and parkland

03: Tasburgh undulating landscape

04: Tasburgh, Fairstead Lane

B1 Tas Tributary Farmland

- Framed open views across the countryside and into adjacent character area
- Settlements characterised by a small number of large villages including Long Stratton, with smaller hamlets and scattered farmsteads dispersed across the wider landscape, frequently clustered with small areas of woodland
- Agricultural buildings occur at intervals across the landscape, the more traditional being built of red brick, together with many timber-framed houses and thatched cottages
- Churches are a distinctive feature within this landscape and are visible across the character area when located on areas of higher ground including round towered churches at Topcroft, Fritton and Aslacton and square towered churches of Stratton St Michael and Tibenham
- Mixed vernacular of timber-frame, stepped and Dutch gables, thatch and round towered churches

05: Saxlingham Nethergate

06: Stratton St Michael

07: Saxlingham Green

08: Shotesham

09 : Hempnall

B5 Chet Tributary Farmland

- Flat to gently undulating landscape
- Settlement is dispersed across the character area and is generally compact, often clustered around greens of 12th or 13th century origin, with intricate network of minor roads
- Areas of historic parkland and some moated sites such as Moat Farm to the south of Kirstead Green
- Distinctive and extensive areas of common land and smaller village greens
- Norman round towered churches are a distinctive feature of the landscape, either within villages or as isolated landmarks, forming very visible features on the highest ground, generally built of brick and flint
- Most villages have a distinctive core comprising red brick and timber-framed houses with mixed building styles and materials at the more recent, suburban edge. Village ponds are also a feature
- Large farm buildings and farm processing units occur throughout the landscape with older farm buildings being characteristically red brick and tiled

10: Woodton

11: Seething

C2 Thurlton Tributary Farmland with Parkland

- Land rising gently from low lying Waveney valley with areas of flatter plateau cut by narrow tributaries
- Presence of large estates with associated 18th and 19th century halls and distinctive historic parkland
- Relatively sparsely settled, villages mainly residential with absence of centre/core
- Isolated and round tower churches are key features and prominent in views. Red brick barns occur as landmark features
- Modern development plus traditional vernacular of red brick, Dutch and stepped gable ends

E2 Great Moulton Plateau Farmland

- Flat, elevated plateau landform
- Large scale landscape of openness and exposure
- Number of greens and commons
- Distant views and farm buildings, some of large scale, exposed and visible in the open landscape
- Timber-framed houses and associated moats
- Distinct absence of churches within the landscape
- Sparsely settled with scattered farmhouses and farm buildings, some linear settlement with absence of centre/core

12: Tivetshall

2.5 The Historic England Farmstead and Landscape Statement for the South Norfolk and High Suffolk Claylands National Character Area, identifies the historic character of traditional farmsteads and their buildings within the area and how they relate to their surrounding landscape. This notes that the area is an intensively farmed landscape predominantly under arable cultivation, with 98% of the Character Area being open landscape and 90% of that land under cultivation. Less than 2% of the Character Area

is urban or classified as non-agricultural, while 3% is wooded. Although the landscape underwent significant change following World War II, mostly in the form of boundary removal, much still survives from earlier centuries including greens and their ditches, moats, mediaeval or earlier lanes and field boundaries. There is a high survival of traditional farmsteads in this area, their significance being enhanced in the context of mediaeval moated sites, coherent patterns of early enclosure, commons and greens. There is also a high survival in a national context of pre-1750 farmstead buildings, particularly farmhouses, but also mediaeval and later aisled and unaisled barns, stables, cartsheds and granaries. Their significance is enhanced in the context of mediaeval field boundaries. Some barns in the area display an exceptionally early use of brick by national standards. Thatch was the predominant roofing material for most farm buildings into the 19th century and surviving examples are important to the local distinctiveness of the character Area. Clay lump buildings, most from the 19th century, are also significant survivals.

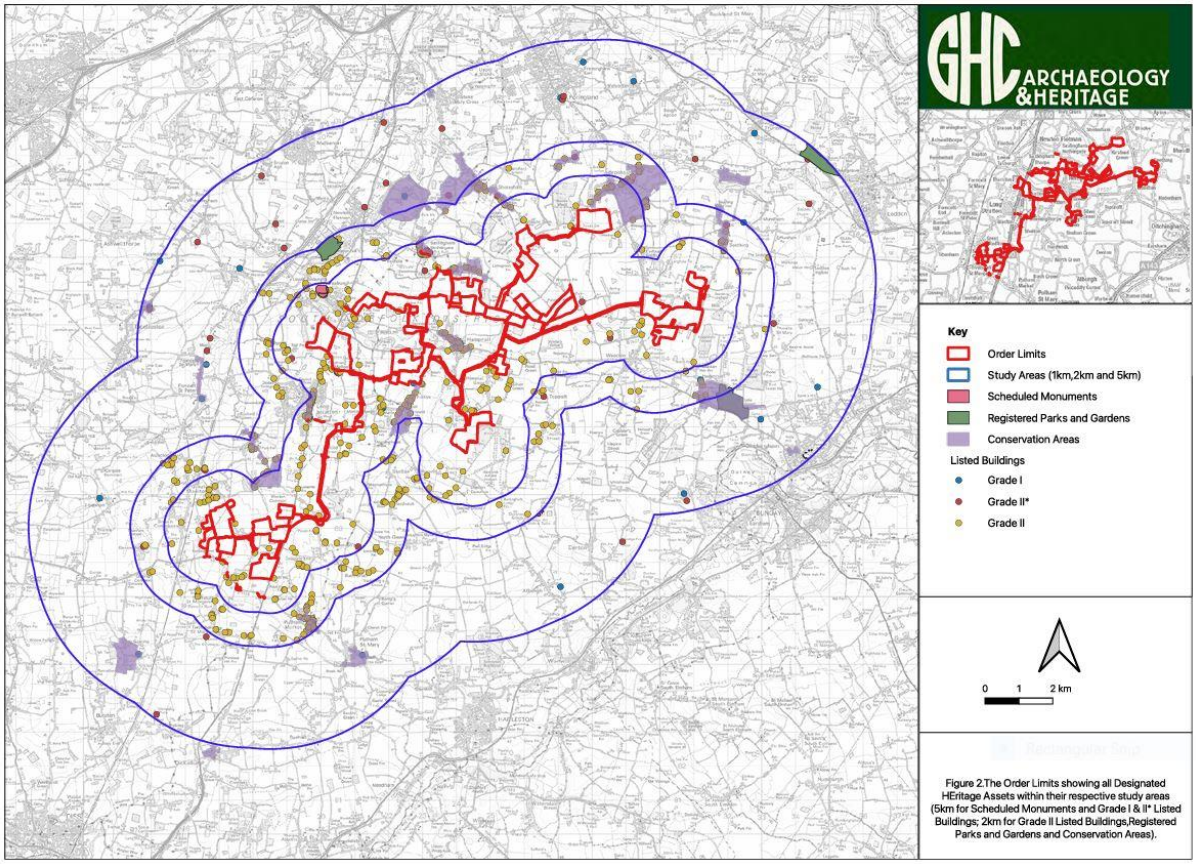
2.6 The landscape within which the proposed development sits has a distinctive rural character and a strong sense of place with its predominantly open, green, and agricultural qualities. There is a fundamental intrinsic relationship between the locally distinctive traditional buildings and their surrounding landscape, which are rooted in their location having been constructed from locally available materials. Buildings sit within this landscape which positively contribute to its character, whilst the landscape forms an important element of their setting. Settlement patterns, land form, field patterns and boundaries, commons and greens, traditional farmsteads and their buildings, vernacular buildings and historic churches, all combine to create the historic and cultural characteristics of the landscape as a whole, which although it has changed and evolved over time, still remains a predominantly open and agricultural landscape which is largely undeveloped.

13: Fritton Common

3.0 Environmental Statement: Cultural Heritage

3.1 An Environmental Statement supports the application with Volume 1: Chapter 10 relating to Cultural Heritage. This includes an assessment of potential effects upon designated and non-designated heritage assets during the construction stage and potential effects upon designated and non-designated heritage assets due to changes in their settings during the construction, operational and decommissioning phases of the scheme. Section 10.5 sets out the scope and methodology for the assessment of the impacts of the scheme on Cultural Heritage.

3.2 The Heritage Statement for the scheme is provided in Volume 3: Appendix 10.1 Parts 1, 2, 3 and 4 of the Environmental Statement. Following an initial assessment of those designated heritage assets identified within 5km and 2km of the Order Limits (see the location plan 06 below), through a combination of desk-based research, viewshed analysis and site visits, a total of 51 designated heritage assets were scoped in for further assessment. This includes one Scheduled Monument, two Grade I listed buildings, two Grade II* Listed Buildings, 42 Grade II Listed Buildings and four Conservation Areas.



14: Location of Designated Heritage Assets in relation to the Order Limits (5km for Scheduled Monuments, Grade I and Grade II Listed Buildings; 2 km for Grade II Listed Buildings, Registered Parks & Gardens and Conservation Areas)*
© GHC Archaeology & Heritage

3.3 The statement includes an assessment of the significance of those heritage assets identified as potentially affected by the proposed scheme, including their setting, along with an impact assessment of the development, based on good practice advice published by Historic England. This is supported with a number of illustrations including photographs and heritage viewpoints. The scheme includes a number of mitigation measures mainly comprising tree planting and hedgerow reinforcement to minimise any harmful impact on the significance of heritage assets.

3.4 The Heritage Statement concludes that with the exception of two designated heritage assets, the level of impact arising from the proposed development is considered to be negligible in general and causing no harm. In both cases, where the potential to cause some harm has been identified, this is considered to be less than substantial at the lower end of the scale through minor adverse impacts arising from changes to their setting.

4.0 Assessment of significance and setting of heritage assets affected

4.1 The starting point of any analysis is to identify those heritage assets likely to be affected by the proposed development, as set out in the first stage of the Historic England Guidance. The National Heritage List for England and the Norfolk Historic Environment Record have also been consulted. Site visits were carried out over a period of five days during April 2026 to assess all 10 sites and their context and the significance and setting of assets affected. This includes all 51 designated heritage assets identified in the Environmental Statement submitted with the application, as potentially affected by the proposed development, along with a number of additional heritage assets, due to their proximity to the proposed site boundaries.

4.2 The second stage of the Historic England Guidance, is to assess whether the setting of a heritage asset makes a contribution to its significance and the extent and/or nature of that contribution. This should initially address the key attributes of the heritage asset itself and then consider

- the physical surroundings of the asset
- the way the asset is appreciated
- the asset's associations and patterns of use

4.3 'Significance' is defined in the NPPF glossary as *'The value of a heritage asset to this and future generations because of its heritage interest. That interest may be archaeological, architectural, artistic or historic. Significance derives not only from a heritage asset's physical presence, but also from its setting'*

4.4 'Setting' is also defined in the NPPF glossary as *'The surroundings in which a heritage asset is experienced. Its extent is not fixed and may change as the asset and its surroundings evolve. Elements of a setting may make a positive or negative contribution to the significance of an asset, may affect the ability to appreciate that significance or may be neutral'.*

4.5 The Historic England Guidance provides a checklist of potential attributes of a setting to assist with assessing the extent that setting contributes to significance. In particular, it is noted that settings of heritage assets which closely resemble the setting at the time the asset was constructed are likely to contribute particularly strongly to significance. It is also important to recognise that setting is dynamic and the relationship between an asset and its surroundings changes as one moves around. Setting is not simply about views or experience from a single viewpoint and there are a number of key considerations which need to be taken into account in defining the setting of a heritage asset and how it contributes to significance. The attributes of setting in relation to physical surroundings include topography; associative relationships with other heritage assets; scale and grain of surrounding landscape and

spaces; green space, trees and vegetation; openness, enclosure and boundaries; history and degree of change over time. Key elements in relation to experience of the assets include surrounding landscape character; views from, towards, across and including the asset; visual dominance, prominence or role as a focal point; tranquillity, remoteness, wildness; sense of enclosure, seclusion, intimacy or privacy; land use.

4.6 **Sites 1 and 2 and BESS**: There are 7 Grade II listed buildings in close proximity, including Broadgate Way to the south-west of site 1A, Moulton Farmhouse to the east of site 1B, Laurels Farmhouse and Laurels Farm Barn to the north of site 1B, Hill House to the east of site 2A, Frenchs' Farmhouse to the east of site 2C and Barn Cottages to the south of the BESS.

4.6.1 **Broadgate Way, Great Moulton** is a timber framed and rendered 17th century cottage with a steeply pitched pantile roof, gable ends and a central brick chimney stack, with later alterations and extensions. Its significance is derived from its architectural and historic interest, being a typical, locally distinctive, vernacular building of simple traditional form and materials. In terms of its setting, it is experienced mainly in views from Broadgate Lane, along with open views across the agricultural land to the west. It sits in a relatively isolated location and there is some degree of seclusion, being surrounded by a number of mature trees and vegetation. Apart from the addition of a dwelling immediately to the north and a couple to the south, there has been little change in its setting since the first edition OS Map of 1884, where it is shown as being surrounded by open agricultural land. This rural and relatively undeveloped setting positively contributes to the experience of the building and its overall significance.

15 & 16: Broadgate Way seen from Broadgate Lane

4.6.2 **Moulton Farmhouse, Great Moulton** (now known as Woodlands Farm), is a 17th century timber framed and rendered farmhouse with a steeply pitched gable ended thatched roof and an external brick chimney stack at the south end. There is a later 17th century addition to the north with a lower thatched roof and a brick chimney stack at the junction and a further lower extension beyond, with a pantile roof. As an important example of the scattered farmsteads throughout this area, the significance

of the building is derived from its architectural and historic interest. The farmhouse is in an isolated location, surrounded by open agricultural land, which forms the setting of the building. There are several important views to the north and south along Frith Way as well as to the east and west, where the buildings are experienced in this open, undeveloped farmland. There are also important historic associations between the farmhouse, its associated outbuildings and the surrounding agricultural land, which, apart from changes to the field pattern, remains open and undeveloped as evidenced from map regression, particularly the first edition OS Map of 1884. As a consequence. its setting makes an important contribution to the overall significance of the farmhouse.

17-22: Moulton Farmhouse and its setting

23: Moulton Farmhouse & outbuildings, OS Map 1884 © National Library of Scotland

4.6.3 **Laurels Farmhouse, Great Moulton** is an early 17th century timber framed and rendered house with a steeply pitched pantile roof with gable ends and a central brick chimney stack. It has a two storeyed gabled porch to the front and rear and a 16th century timber framed wing to the west end with a pantile roof. The farmhouse is listed for group value with the **Barn to the east of Laurels Farmhouse**, which is separately listed. The barn dates from the 17th century and is timber framed and rendered with a steeply pitched gable-ended roof. Together they form an important group and are mainly appreciated in views from High Green, although they are set back from the street and are relatively secluded, being surrounded by mature trees and vegetation. The 1884 OS Map shows the buildings having an open aspect to the east with parcels of undeveloped land, although this has since been infilled with residential development. There are open views from the buildings towards the south and views towards the buildings to the north, across open farmland which forms their setting, where their roofscape and chimneys are visible and form the backdrop to these views.

24 & 25: Laurels Farmhouse and Barn in views to the south from the street

26 & 27: View north towards Laurels Farmhouse and open farmland to the south

4.6.4 **Hill House, Pulham Market** dates from 1836 designed by William Thorold as a workhouse, now subdivided and converted to residential use. Built of red brick with blue headers and slate roofs, it has a central octagon with a bellcote and four 3-storey wings with a cross plan, linked at the ends by single storey ranges forming an octagonal plan overall. It is an imposing and prominent building with the principal west façade having a pedimented gable with a large first-floor sash window with glazing bars and a main entrance door with a cornice hood on brackets, flanked by lower wings also having sashes with glazing bars. Its significance is derived mainly from its architectural interest along with its historic use and community value as a former workhouse. Set back from the adjoining road it is mainly appreciated in views towards the east, where it is seen as a highly visible feature in the landscape. It is largely surrounded by flat areas of farmland which form its setting in views to the north and south along the road. With the exception of the garden centre building to the south-east, its setting has remained relatively unchanged. Many of the occupants of the workhouse in the 19th century are likely to have worked in the surrounding fields and its historic connection with this open setting, contributes greatly to its significance.

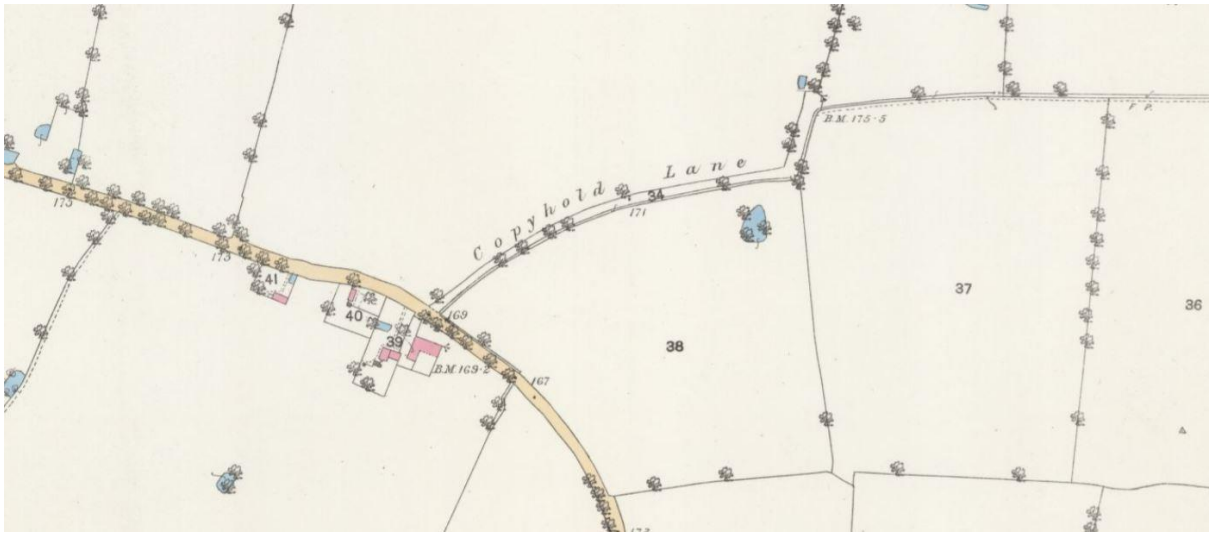
28 & 29: West façade of Hill House and open setting to the north and west

4.6.5 **French's Farmhouse, Pulham Market** is a three storey house dating from the 18th century, roughcast with a low pitched pantile roof with gable ends and a central pilastered doorcase. To the north is a further wing, possibly of earlier date with a steeply pitched pantile roof with gable ends. Its significance is derived mainly from its architectural and historic interest as an isolated farmstead along with its associated outbuildings to the north-west which are shown on the 1884 OS Map. With the exception of the farm shop which has been developed immediately to the north, its setting is relatively unchanged, being surrounded by areas of open, flat farmland. Its setting contributes to its overall significance due to the historic association with this agricultural land. The farmhouse is relatively secluded being surrounded by mature trees and vegetation, although it is appreciated in many views in the open setting with greater visibility in the winter months.

30 & 31: French's Farmhouse surrounded by open farmland in views to the west

4.6.6 **Barn Cottages, Tivetshall St Margaret** are a pair of 17th century, timber framed and rendered cottages with a thatched roof and gable ends, an internal brick, off centre, chimney stack, casement windows and boarded doors. Its significance is derived from its architectural and historic interest as a locally distinctive, vernacular building of simple form, traditional materials and details. It is relatively isolated and sits surrounded by open farmland and can be appreciated as a distinctive building in many views, particularly in views towards the north, together with several viewpoints from the winding road. With the exception of the small terrace of dwellings on the opposite side of the road, map regression shows that its setting has remained open and undeveloped, as illustrated on the first edition OS Map of 1884. This open, rural farmland setting, positively contributes to the overall significance of the building, particularly through historic associations between the cottages and surrounding land and the likelihood of occupants working as part of the local farming community.

32-38: Barn Cottages in views to the south and north-west



39: Barn Cottages and adjacent buildings to the east OS Map 1884 © National Library of Scotland

4.7 **Site 3**: There are 4 Grade II listed buildings in close proximity, including Townhouse Farmhouse, Rose Cottage, Three Feathers and the Barn and Stable Range adjoining Three Feathers. all located to the north of site 3. All of these buildings are noted as being of group value as they form an important group with other listed buildings in Lundy Green.

4.7.1 **Townhouse Farmhouse, Lundy Green, Hempnall** is a 17th century timber framed house which was encased in brick in the 20th century. It has a steeply pitched roof with gables, a brick chimney stack off centre and an external stack at the end. There are a number of associated outbuildings immediately to the east. It is mainly appreciated in views along the street where it is seen amongst other surrounding buildings which form a tightly knit group and create a sense of enclosure. In contrast, to the rear of the building, there is open farmland and there are long, distant views to the south from the street where there is a gap alongside the outbuildings, with this area forming its wider setting.

40 & 41: View west along the street and open farmland to the south

4.7.2 **Rose Cottage, Lundy Green, Hempnall** is a 17th century timber framed and rendered house with a thatched roof and gable ends, a brick chimney stack off centre and external end stack. It has mullion windows, a plank door and gabled dormers. It is located on the north side of the street and set back with glimpses of the building through surrounding trees and vegetation. It is mainly appreciated from the street along with other surrounding buildings. There are views from the building to the open farmland to the south.

42 & 43: Rose Cottage looking north and along the street to the west

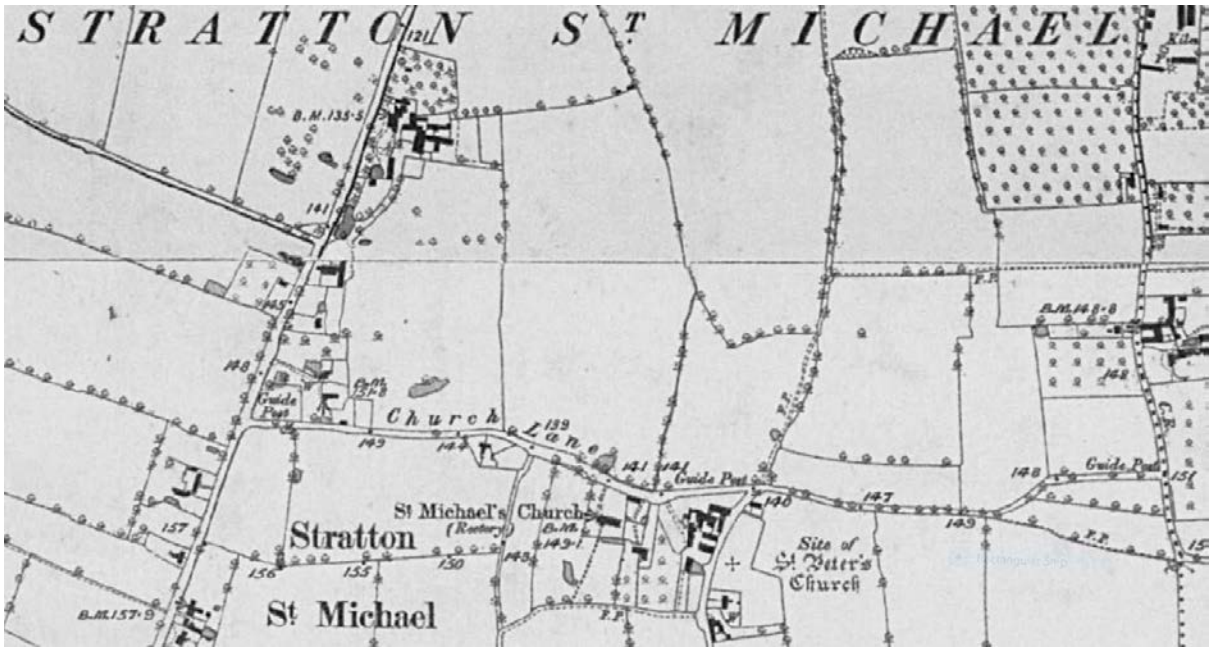
4.7.2 **Three Feathers, Lundy Green, Hempnall** is a timber framed and rendered house dating from the 17th and 18th centuries with a steep black glazed pantile roof and a central brick chimney stack. The **Barn and Stable Range** adjoining **Three Feathers** is separately listed and dates from the early-mid 19th century. This long range of former small stables is of plastered clay lump construction with a pantile roof and a further small barn of painted flint with brick dressings and a pantile roof adjoins to the south-west. Their significance is derived from their architectural and historic interest and in particular the use of locally distinctive materials and details. Their setting is mainly appreciated in views from the street where they are seen together with surrounding buildings.

44 & 45: Three Feathers, Barn & Stable Range looking west along the street

4.8 **Site 4**: There are 9 listed buildings in close proximity, including the Grade I listed Church of St Michael and the Grade II* listed Old Rectory, both to the south of site 4B and the following Grade II listed buildings: Barn to the north of the Old Rectory, Cottage occupied by [redacted] and Church Farmhouse to the south of site 4B; The Cedars, Pair of houses occupied by [redacted] and Cottage occupied by [redacted] to the west of site 4B and The Hollies to the east of site 4A.

4.8.1 As a high status, Grade I listed building, the significance of the **Church of St Michael, Stratton St Michael, Long Stratton** is derived from its considerable architectural, historic, archaeological and artistic interest. Dating mainly from the 14th century, including the nave and chancel with arch braced roofs, it has a south porch and a low tower with moulded coping to the parapet and a later wooden bellcote. Built of flint with a pantile roof there is evidence of 15th, 17th and 18th century work. As the principal building within the hamlet of Stratton St Michael, it has considerable communal value as the spiritual focus of community life for many centuries as well as being a key part of the traditional rural scene, making an important contribution to locally distinctive character and creating a strong sense of place. The immediate setting of the church is formed by the green and open space of the churchyard which surrounds the church and although there is some degree of enclosure by hedgerows and mature trees, there are several views looking out where the church can be seen along with the surrounding, undeveloped, agricultural land, particularly towards the north, with the degree of visibility increasing during the winter months. There are also several locations within the churchyard where there are views of the Grade II* listed Old Rectory which lies immediately to the south-east and the Grade II listed barn in close proximity, to the north-east of the church. These two buildings form a key element of the setting of the church and as a group, have an important association with each other, both historically in terms of their use and purpose, as well as visually. Considering the degree of change over time, map regression shows that the physical relationship between these buildings and the church along with the surrounding open and undeveloped, rural landscape, remains much the same today, as at the time of their of development in the 16th and 17th centuries. This same relationship can be seen on the first edition Ordnance Survey map of 1884. However, it must be noted that the recent construction of the Long Stratton bypass and associated works immediately to the south of the church has changed its setting, with some degree of visual intrusion and the otherwise tranquil experience of the churchyard has been affected by the noise of vehicles travelling along the bypass. Although this has resulted in a negative impact, part of the recent works have included the construction of a public footpath to Long Stratton and a new footbridge over the road. This has created and opened up an important viewpoint where the church can be appreciated in its wider landscape, particularly in views towards the north and north-east, where the open, undeveloped agricultural setting forms the backdrop and defines the long term historic use of the surrounding land. There are further viewpoints looking south towards the church from within the agricultural land where the church tower with its

bellcote, can be appreciated as a distinctive and isolated feature amongst the trees. The character of this land helps to illustrate its historic development as a mediaeval parish church and complements its value as a building which for centuries served as a spiritual centre for a small, but primarily rural and agricultural community. Its relative isolation, reinforced by the undeveloped agricultural landscape are key attributes of the setting of the building, which positively contribute to its overall significance.



46: First edition OS Map of 1884 Stratton St Michael © Norfolk Historic Maps Explorer With the exception of the recent construction of the Long Stratton bypass to the south of Church Lane and some changes to field boundaries, there has been very little new development since then.

47 & 48: Views of the Church of St Michael from within the churchyard looking north-east and north-west

49: View to the north-east from the new footbridge where the Church of St Michael, the Old Rectory and Barn to the north can all be seen together with open agricultural land beyond forming their setting

50 & 51: View towards open farmland to the north from within the churchyard and view to the south from open farmland where the Church tower is an important feature with its distinctive bellcote and the Barn to the north is also visible

4.8.2 **The Old Rectory, Stratton St Michael, Long Stratton** is a Grade II* listed, high status timber framed building dating from the 16th century. The ground floor is rendered with the first floor being jettied and supported on curved brackets with close studded timber framing. It has a steep pantile roof and a central brick chimney stack with the west end having a steeper pitched and hipped roof. The lower rear wing to the south is also timber framed and plastered with a brick chimney stack. Its significance is derived from its considerable architectural and historic interest. In addition, it forms part of an important group, having historic associations and visual connections with the adjacent Grade I listed Church of St Michael and the Grade II listed Barn immediately to the north. In terms of its setting, it is set back from Church Lane and views towards the south of the principal façade are restricted by surrounding mature vegetation. There are a number of views towards the east from within the churchyard where the principal façade and roof of the building are visible. However, it is in wider views towards the north-east where it can be appreciated along with the church and

barn, including from the green open space immediately to the south-east of the church, but in particular, from the footpath and footbridge where all three can been seen with the open and undeveloped agricultural land beyond forming their setting. This spatial and visual relationship between the three buildings has remained unchanged for centuries, with the open setting of the agricultural land beyond making an important conribution to understanding the function and significance of the Old Rectory.

52 & 53: View of the Old Rectory looking east from within the churchyard

54: View to the north-east where the Church and the Old Rectory can be seen together

4.8.3 The **Barn to the north of the Old Rectory, Stratton St Michael, Long Stratton** is a Grade II listed, timber framed and plastered building originating from the 17th century with a pantile roof and modern weatherboarding to the north elevation. The section to the east was rebuilt in the 19th century in red brick and there is a further addition with a lower pantile roof originally used as stables, although the building is now in residential use. Its significance is derived mainly from its architectural and historic interest as a traditional vernacular building of simple form and character. The barn is mainly experienced in views along Church Lane, being located immediately to the south. There are also several views from within the churchyard where it is seen in conjunction with the Church and the Old Rectory. In views to the north, also from within the churchyard, the open, undeveloped agricultural land form the backdrop, which is visible through the trees, particularly during the winter. The barn is also visible in views

towards the south from the surrounding open land, together with the church tower. From the new footpath and footbridge there are wide panoramic views towards the north-east, where the barn, the Church and the Old Rectory can all be seen together as an important group with the open agricultural land beyond. This undeveloped, open setting positively contributes to the significance of the barn.

55 & 56: The Barn looking west along Church Lane and view to the north from within the churchyard with open farmland beyond

57 & 58: View of the Barn looking north-east from within the churchyard with open farmland beyond and view looking south across open farmland towards the Barn and the Church tower

4.8.4 The **Cottage occupied by [redacted], Stratton St Michael, Long Stratton**, (now referred to as the Thatched Cottage), is a Grade II listed, timber framed and plastered building dating from the 17th century. It has a thatched roof with gables, an eyebrow dormer, brick chimney stack and casement window. Its significance is derived from its architectural and historic interest as a simple, traditional vernacular building, built within a small rural and agricultural community. It is mainly experienced in views along Church Lane being located immediately to the south. Although its setting to the south has changed with the recent construction of the bypass, there are several wide views to the north, including from the new footbridge where the

surrounding agricultural land forms its setting. The cottage has a historic association with this land, with its occupants likely to have worked as part of the local farming community and this setting makes an important contribution to its significance.

59-62: Views of the Thatched Cottage to the east and west along Church Lane and to the south and north, across and towards surrounding open farmland forming its setting

63: The Thatched Cottage looking north-east across the recent works associated with the new bypass with open land beyond forming its wider setting

4.8.5 **Church Farmhouse, Stratton St Michael, Long Stratton** is a Grade II listed, timber framed and roughcast building originating from the 16th century with later alterations. It has a pantile roof with gable ends and two brick chimney stacks, the gable to the south being brick faced. It has traditional casement windows and a mullion

window to the rear at first floor level along with a short gabled wing to the rear. Its significance is derived mainly from its architectural interest and its historic use as part of a traditional farmstead. It occupies a relatively secluded position with Its principal façade facing west, although it is screened by mature trees and vegetation in views to the south from Church Lane. The east facing rear is seen from the adjoining track, although this is experienced amongst several surrounding mainly traditional ancillary farm buildings, predominantly of brick and pantile construction. There are limited views and glimpses of the farmhouse as a consequence of surrounding buildings and trees with its setting being tightly defined.

64 & 65: Church Farmhouse looking west from the adjoining track with surrounding ancillary farm buildings forming its setting

4.8.6 **The Cedars, Long Stratton** is a Grade II listed grey brick building with a slate roof. The west facing block dates from the late 18th century and is an imposing three storey building, with the principal façade having sash windows and a central doorway with fluted pilasters and entablature, rectangular fanlight and panelled door. The east facing block is the original house dating from the 17th century or earlier and is timber framed and plastered with a steeply pitched pantile roof with gable ends. The Cedars is set amongst a number of mature trees and adjoins the A140 which is immediately to the west and there are a number of other buildings immediately to the south and to the east, beyond which it is surrounded by open areas of farmland. The building is seen in various views when travelling along the A140 along with and in between the surrounding trees and vegetation. The principal façade is seen in views to the east and the north-east from the open land to the west of the A140. There are also views to the north from Church Lane where the façade of the original 17th century house is visible amongst the surrounding trees and adjoining buildings along with views looking west across open farmland, where the roof and chimneys of The Cedars are seen above the surrounding buildings. The open character of the land which surrounds The Cedars and the cluster of adjoining buildings set amongst mature trees, forms its wider setting and having remained undeveloped for many years, positively contributes to its overall significance.

66 & 67: Setting of The Cedars in views to the east and north-east from the open farmland to the west of the A140

68 & 69: Setting of The Cedars in views across open land looking north from Church Lane and across open land looking west

4.8.7 The Grade II listed **Pair of houses occupied** [redacted] **Long Stratton** date from the late 17th or early 18th century. Constructed from plastered and painted brick with the east end faced in later red brick and a steep tiled roof with gables and brick chimney stacks. The adjacent Grade II listed **Cottage occupied by** [redacted]**, Long Stratton**, (now known as Well Meadow Cottage) dates from the 17th century. It has a plastered and painted brick gable end with a steep pantile roof, wedge shaped dormer and central brick chimney stack. Well Meadow Cottage is accessed from the A140 and sits in a relatively secluded position behind and immediately to the north of the pair of houses which face onto and are accessed from Church Lane which forms their setting in views to the north. There are views of the surrounding open land to the north and east, as well as views looking west towards the buildings across this open land, which forms their setting. There are historic associations between these cottages and the surrounding agricultural land, with occupants likely to have contributed to the work of the local agricultural community. This open, agricultural land which forms their wider setting therefore contributes to understanding the function and significance of these buildings.

70 & 71: Pair of houses and Well Meadow Cottage beyond looking north and north-east from Church Lane

72 & 73: Adjoining open farmland immediately to the east and view looking south-west over open farmland towards the buildings

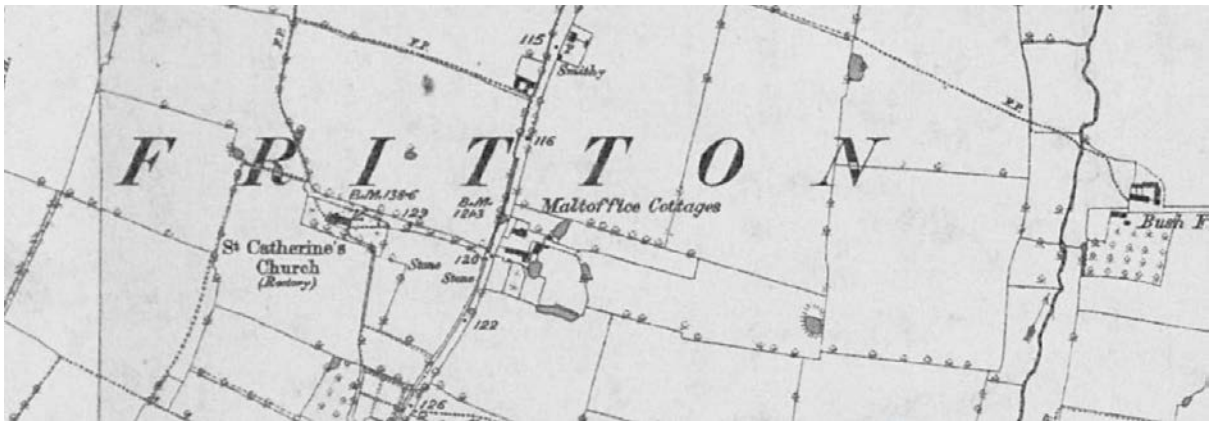
4.8.8 **The Hollies, Morningthorpe and Fritton** is a Grade II listed early 19th century, two storey, red brick house with a low pitched and hipped black pantile roof. The west facing, symmetrical principal façade has sash windows with glazing bars and a central pilastered doorcase. The north end has a late 19th century bay window. The main façade of The Hollies faces west onto Brick Kiln Lane. Although there are a number of surrounding mature trees and vegetation, there are glimpses of the building in views from the lane, particularly looking east from the two access driveways. There are a number of adjoining buildings to the north and east referred to as Hollies Farm Barns and although the land to the west is open farmland, mature trees and vegetation limit wider views of the building and its setting is therefore relatively restricted, with the building generally being experienced in close proximity rather than from a wider setting.

74 & 75: The Hollies looking east from the access driveway off Brick Kiln Lane and open farmland to the west with screening from mature trees and vegetation

4.9 **Site 5**: There are 3 listed buildings in close proximity including the Grade I listed Church of St Catherine to the south of site 5B and the Grade II listed Church Farmhouse and the Barn to the north-west of Church Farmhouse, both to the south-east of site 5B. In addition, Fritton Conservation Area lies immediately to the south and adjoins the south-east boundary of site 5B.

4.9.1 The **Church of St Catherine, Morningthorpe and Fritton** is a high status, Grade I listed building, its significance being derived from its considerable architectural, historic, archaeological and artistic interest. Built of flint rubble, brick and stone dressings with a slare roof, the round tower is of 12th century origin, with an octagonal belfry stage added in the 15th century and a later embattled parapet. There is a 12th century north doorway to the nave, a 15th century south porch and 19th century Perpendicular windows to the nave. There are several internal features which make an important contribution to its significance including 15th century wall paintings and an octagonal font and early 16th century dado to the rood screen with eight painted panels including the donor [redacted] and his family. The church stands amongst surrounding fields in an isolated and secluded location some distance away from the village which lies to the south. A path from the road leads up to the oak lychgate of the churchyard which was gifted by [redacted] in 1879. Upon arrival at the green and open space of the churchyard, which forms the immediate setting of the church, there is a distinct sense of peace, tranquillity and isolation. Although there is some degree of enclosure of the churchyard by mature trees and vegetation as well as along the path from the east, there are several views out, particularly to the north over the surrounding, undeveloped agricultural land, with the degree of visibility increasing during the winter months. Considering the degree of change over time, map regression shows that the relationship between the church and the surrounding rural landscape, remains much the same today, as at the time of development which can be seen at the time of publication of the first edition Ordnance Survey map in 1884. The character of this land helps to illustrate its historic development as a mediaeval parish church and complements its value as a building which for centuries served as

a spiritual centre for a small, but primarily rural and agricultural community. Its relative isolation, reinforced by the surrounding undeveloped agricultural landscape are key attributes of the setting of the building, which positively contribute to its overall significance. As the principal building within Fritton, it is a key part of the traditional rural scene, making an important contribution to locally distinctive character and creating a strong sense of place.



76: First edition OS Map of 1884 Fritton *© Norfolk Historic Maps Explorer*

77 & 78: View to north-west and lychgate from the path looking west

79 & 80: Views from the churchyard to east and north towards surrounding open land

81 & 82: Pathway to lychgate entrance to churchyard and views to north over adjoining open land

83-86: Photographs illustrating increased intervisibility between the church and the surrounding open land during winter months [redacted]

4.9.2 **Church Farmhouse, Morningthorpe and Fritton** is a Grade II listed, timber framed and plastered farmhouse dating from the 17th century. It has a steeply pitched pantile roof with gable ends and an off-centre brick chimney stack. The **Barn to the north-east of Church Farmhouse, Morningthorpe and Fritton** is a 17th or 18th century timber framed, plastered and weatherboarded barn with steeply pitched gable

ended roof. Together the farmhouse and barn form an important group. Both buildings are mainly appreciated in views towards the east when travelling along The Street with the barn adjoining and set at right angles to the road and the farmhouse set back within the site. Their wider setting is formed by open and undeveloped farmland which surrounds the properties and due to historic associations between the buildings and land, this rural landscape setting positively contributes to an understanding of their historic function and significance.

87 & 88: Views of the barn and farmhouse looking east from The Street

89 & 90: Open farmland rising to the west immediately opposite the entrance to Church Farmhouse from The Street and view to the east from the path adjoining the churchyard towards Church Farmhouse and Barn

4.9.3 **Fritton Conservation Area**, originally designated in 1976, lies immediately to the south of site 5B and adjoins the site boundary to the south-east corner. Key characteristics include:

- Large well-preserved grazed common with numerous ponds which are important natural habitats
- Concentration of dwellings at the north end of the hamlet
- Importance of verges with buildings set back behind hedges

- Variety of vernacular architecture including a number of thatched buildings

The Conservation Area is distinctly rural in character with buildings dispersed around the common, which back onto surrounding agricultural land. The common is well enclosed by mature trees to the perimeter and feels separate from the relatively flat surrounding countryside, creating its own distinctive sense of place.

91: View to north from Fritton Common

4.10 **Site 6**: There are 3 listed buildings in close proximity. However, Site 6 is now to be retained for habitat management with no built development proposed within the site. As a consequence, there will be no changes to the setting of surrounding heritage assets and they have therefore been scoped out of further assessment.

4.11 **Sites 7A – 7C**: There are 7 Grade II listed buildings in close proximity including The Countryman Public House and Hill Farmhouse to the west of site 7A, Tramp's Hall and Barn to the east of Tramp's Hall, both to the south of site 7A, the Former Quaker Meeting House to the south-west of site 7A and Wood Farmhouse and Grove Farmhouse to the south of site 7C.

4.11.1 **The Countryman Public House, Tasburgh** is a Grade II listed 18th century, three storey, stuccoed brick building with a pantile roof, Dutch gables and sash windows. There is a single storey wing to the south and a two-storey wing to the east, both with hipped pantile roofs. It adjoins the A140 and is seen as a prominent building due to its 3-storey height and Dutch gabled form, in views mainly towards the east when travelling along the road. Its wider setting is formed by the undulating and gently rising farmland of the Tas Rural River Valley which form the distant backdrop to the building in views to the east. There are also views from the open farmland towards the west where the building is seen as a feature on the horizon amongst the surrounding mature trees. Although there are no historic connections between the

use of the land and the building as a public house, the surrounding land forms the wider landscape setting within which the building is appreciated.

92 & 93: Views towards the north-east and south-east from the A140 with open farmland forming the backdrop

94 & 95: Setting of The Countryman in views to the west from open farmland

4.11.2 **Hill Farmhouse, Tasburgh** is a Grade II listed 17th century timber framed and plastered farmhouse with a steeply pitched slate roof, brick chimney stacks, wedge shaped dormers, sash windows and a pilastered doorcase. It occupies a prominent position on the main A140 Long Stratton Road at the junction with Fairstead Lane and is seen in views when travelling along the road, mainly towards the north-east and south-east. There are a number of ancillary farm buildings immediately to the north and from the main access drive there are views towards the east where the surrounding open and undulating farmland within the Tas Rural River Valley forms the setting of the building. There are also views towards the west from this open farmland where the farmhouse and its ancillary buildings are seen within a rural landscape setting. There are historic associations between the farmhouse and the use of the surrounding open land which forms its setting and positively contributes towards the understanding of its historic function and its overall significance.

96 & 97: Hill Farmhouse looking south-east from the A140 and view looking east from the entrance drive with open farmland beyond

98 & 99: View to north-east from the A140 and view towards the west with open and undeveloped farmland forming its setting

4.11.3 **Tramp's Hall, Tasburgh** is a Grade II listed 17th century timber framed and roughcast house with a steep pantile roof with gable ends and a brick chimney stack. The **Barn immediately east of Tramp's Hall, Tasburgh** is a Grade II listed timber framed barn dating from the 17th century with a steeply pitched roof clad in corrugated iron. It has a gabled porch to the east and waggon entrance opposite to the west, and collar and tiebeam roof trusses with curved braces to the tiebeam. Tramp's Hall and the adjacent barn form an important group. The buildings are located on the south side of Fairstead Lane immediately after the junction with the A140 and being surrounded by mature trees and vegetation, occupy a relatively secluded position. The barn sits at right angles and can be seen in views from the lane. However, the hall is set well back within the site and is only glimpsed when passing the entrance driveway. There are more distant views looking west across open farmland where the roof of the barn can be seen within this wider rural setting.

100 & 101: The barn looking east from Fairstead Lane and views to west across open farmland with the roof of the barn seen on the left

4.11.4 **Former Quaker Meeting House, Tasburgh** is a Grade II listed, two storey, early 18th century meeting house now converted into a dwelling, comprising a red brick rectangular block with a black pantile hipped roof, moulded brick eaves course and mullion and transom windows. Located on Quaker Lane to the south side of Fairstead Lane, the building occupies a secluded position and is mainly appreciated in close up views from the entrance driveway. There are more distant views looking towards the south across open farmland where the roof of the building is seen above surrounding hedgerows, although it is not a particularly prominent feature as it is set against a backdrop of mature trees.

102: View looking south across open farmland

4.11.5 **Wood Farmhouse, Hempnall** is a Grade II listed 17th century brick house with a steep black glazed pantile roof with parapeted gable ends, brick chimney stacks, a moulded doorcase with cornice and a panelled door. It is located at the end of a long track to the north of Fairstead Lane and is seen within a wide, open landscape setting. There a number of ancillary and other buildings surrounding the farmhouse and an area of woodland to the west, with open farmland to the north and south. There are important historic relationships between this wider landscape setting and the

traditional rural farm buildings which sit within an open agricultural context, which positively contributes to their significance.

103: Wood Farmhouse in centre looking north from Fairstead Lane

4.11.6 **Grove Farmhouse, Hempnall** is a Grade II listed, timber framed and plastered house dating from the 17th century. It has a brick faced wall to the south end, a steeply pitched slated roof with gable ends, a brick chimney stack off centre and an external end stack. It is located at the end of a long track from Fairstead Lane and sits parallel to the track with its gable being visible in distant views from the south. Its principal façade faces east with an adjoining pond forming its immediate setting. There are several single storey brick, flint and pantile ancillary farm buildings immediately to the west and to the north and a wooded area further to the east. There are a number of mature trees and a moat to the south and the buildings are surrounded by open farmland to the north and the south. As traditional rural farm buildings within an open agricultural setting, there are important historic associations between the buildings and surrounding land which positively contributes to their significance.

104 & 105: Immediate setting of Grove Farmhouse in views to the west with the adjoining pond and farm access track looking west with adjoining ancillary farm buildings to the north and west

106 & 107: Adjoining farm buildings in views to the north-west and north with surrounding open farmland beyond

108 & 109: Access track in views to the north-west and north leading to surrounding open farmland

4.12 **Sites 7D – 7H**: There are 5 Grade II listed buildings in close proximity including Manor Cottage, Manor Farmhouse and Manor Farmhouse Barn to the north-east of site 7D and Hill Cottages and Hill House to the north of site 7D. In addition, the Grade II listed Holly Cottage lies to the north of site 7F and although it has been scoped out of further assessment in the Heritage Statement submitted with the application, it has been included because it is potentially affected by the proposed development. Saxlingham Green Conservation Area also lies immediately to the north-east of site 7D and to the north of site 7F.

4.12.1 **Manor Cottage, Saxlingham Nethergate** is a Grade II listed rendered and timber framed, former farmhouse dating from the 17th century with later alterations, which was converted into two, but is now a single dwelling. It is two storeys with attic to the east, a pantile roof with off-centre axial chimney stack and a mixed fenestration including two, three and four light metal casements with horizontal glazing bars. The building occupies a prominent corner plot and there are key views from the road towards the south, west and north. It lies within the Saxlingham Green Conservation

Area and marks the entrance into the area on the approach from the south where there is a distinct change in character from open land to built development formed by a small cluster of buildings. Immediately to the south is open undeveloped farmland with distant views looking north towards the building. There are historic associations between the building as a former farmhouse and the open farmland which forms its setting to the south, positively contributing to its significasnce.

110-113: Setting of Manor Cottage in views to the south, west and north from the road

114 & 115: View to north at the entrance to the Conservation Area and view to south across open farmland adjoining the boundary of Manor Cottage

4.12.2 **Manor Farmhouse, Saxlingham Nethergate** is a Grade II listed former farmhouse dating from the 16th and 17th centuries with later alterations. It is timber framed with a pantile roof and has been refaced and extended in colourwashed brick. The original house was extended to the side with a later cross wing then being added. Key architectural features include a mixed fenestration of casements, a blocked mullion and transom window, a moulded stringcourse on the 17th century side extension, platbands to the cross wing, brick chimney stacks, tumbling in to the cross-wing gable and a sloping dormer window. It is located within Saxlingham Green Conservation Area in a prominent corner position at the junction with The Green where there are key views of the building to the west and to the north-east. There is open farmland to the south which forms its wider setting with the building being see in views towards the north across the open landscape. As a former farmhouse there are historic associations between the building and surrounding land with its setting positively contributing to its overall significance.

116 & 117: Setting of Manor Farmhouse looking west and north-east

118 & 119: Approach to the east and setting across open farmland looking north

4.12.3 **Manor Farmhouse Barn, Saxlingham Nethergate** is a Grade II listed timber framed and weatherboarded barn dating from the 17th century which has been converted to a dwelling with a later lean-to extension to the rear. It comprises 13 bays

of a clasped purlin and butt purlin roof with alternate arch braced ties and wind bracing. The barn forms a group with the adjacent farmhouse which historically would have been part of the farmstead. It occupies a slightly more secluded position being set back into the site with its setting being fairly tightly defined, although there are views to the south dominated by the roof and the gable end is seen in views towards the east from the road

120 & 121: The Barn looking to south and gable looking east from the road adjacent to Manor Farmhouse

4.12.4 **Hill Cottages, Saxlingham Nethergate** is a Grade II listed former farmhouse originating from the 16th century which was converted into three cottages and is now a single dwelling. It is timber framed and rendered with colourwashed brick to the front and sides and a thatched roof, casement windows, three eyebrow dormers and brick chimney stacks. It is mainly appreciated in views towards the east where it is set back from the road with an open green frontage. There are also views of the building across open farmland to the west and to the south which forms its wider setting.

122 & 123: Setting looking east across open green frontage from the road

124 & 125: Adjoining open farmland looking south-west along the road and view of Hill Cottages looking east across open farmland

4.12.5 **Hill House, Saxlingham Nethergate** is a Grade II listed large house dating from the 17th century with later 19th century alterations and additions. It is timber framed and rendered with colourwashed brick gable ends and a plain tiled roof. Architecturally the building is quite decorative and distinctive with seven bays of 19th century three-light mullion windows (above) and mullion and transom windows (below) with rectangular hood moulds, three gabled dormers, a pair of small oval windows in each side wing gable end, elaborate moulded gable corbels, crow-stepped gables and brick chimney stacks with octagonal shafts. Mainly appreciated from its open setting to the west, it is slightly set back from the road and is a distinctive building when passing along the street. There are adjacent buildings to the south beyond which is open farmland.

126: Hill House in centre looking north with adjoining buildings to the south

4.12.6 **Holly Cottage, Saxlingham Nethergate** is a Grade II listed cottage dated 1834 on the porch, constructed from rendered clay lump with a colourwashed brick porch and a black pantiled roof. It has four Gothick 2-light casement windows, a rear extension with a catslide roof and a central brick chimney stack with a pair of tall octagonal stacks. Holly Cottage is located with the Saxlingham Green Conservation

Area in an open setting with key views towards the north where it is set back from The Green. Open and undeveloped farmland to the north and south forms its wider setting.

127 & 128: Setting to north and north-west with Holly Cottage set back from The Green

129 & 130: Approach to The Green towards the west and open farmland to the south

4.12.7 **Saxlingham Green Conservation Area** lies immediately to the north-east of site 7D and to the north of site 7F and was originally designated in 1973. Key characteristics include:

- Natural character dominates with the buildings being secondary to it
- Number of fine historic buildings dispersed within the area
- Situated on a ‘plateau’ site to the south east of Saxlingham Nethergate
- Linked to surrounding countryside by a matrix of footpaths and bridleways
- Much of The Green enclosed by mature trees together with hedgerows
- The Green follows the line of the road but is made up of separate areas which provide a series of changing views and vistas

The Conservation Area is defined by the natural elements in the landscape with a series of buildings siting at various intervals within it and it is the interaction between these two components which defines and creates its distinctive character. The area is set amongst a rural agricultural topography, typical of this part of South Norfolk.

Although there is a strong sense of enclosure from mature trees and vegetation with buildings scattered throughout the area, there are a number of important views, from within the area, particularly towards the south, where the open and undeveloped rural landscape which surrounds the Conservation Area can be appreciated. There is a strong sense of arrival when approaching the Conservation Area from the south along Broaden Lane from Hempnall. There is a distinct change in character from wide open views of surrounding farmland to a cluster of buildings which define the west entrance to the Conservation Area.

131 & 132: Views looking south out of the Conservation Area to open and undeveloped farmland beyond

133: Approach to the Conservation Area from the south through open farmland

4.13 **Sites 7I – 7L**: The Grade II* listed Oaks Farmhouse lies to the east of site 7L.

4.13.1 **Oaks Farmhouse, Woodton** is a high status, Grade II* listed house dating from the 16th and 17th centuries which was partly refaced in the 18th century. Of timber framed and brick construction with a pantile roof, its significance is derived from its architectural and historic interest and in particular, its 16th century 2-cell plan and 17th century 3-cell lobby entrance type plan set at right angles, with an L-shaped plan form overall. Key architectural features include 16th century brickwork to the west gable with parapet and kneelers, gable end brick chimney stack, polygonal end turrets to gable corners, moulded brick pediments, diamond mullion to the north wall and a mix

of later casement windows. Map regression shows that the building is located in an isolated location surrounded by open and undeveloped land which still remains today. Although surrounded by some mature trees and vegetation there are views of the building towards the north and the east, with visibility increasing during the winter months. There are also views out from the building across the surrounding land especially to the south and to the west. Its setting in an isolated rural position surrounded by open land which has remained undeveloped for centuries makes an important contribution to its overall significance.

134 & 135: Setting of Oaks Farmhouse in views to the north-east

136-139: Surrounding open farmland in views to the west and the south

4.14 **Site 8**: There are 2 Grade II listed buildings in close proximity, including Upgate Green Farmhouse and the Outhouse north of Upgate Green Farmhouse, both of which are to the north of site 8B.

4.14.1 **Upgate Green Farmhouse, Shotesham** is a Grade II listed 18th century brick farmhouse with a pantile roof. It has a T-shaped plan form and is 2 storeys with 3-light casement windows with horizontal glazing bars at first floor level and transom windows to the ground floor with segmental arches. It has an off-centres porch with pediment, external gable end brick chimney stacks and tumbled in brickwork. Adjoining is the **Outhouse immediately to north of Upgate Green Farmhouse, Shotesham** which is separately listed Grade II. Possibly a former bothy, this 18th century two-storey building is brick and pantile. It has horizontal lattice ventilation openings beneath segmental brick arches and a gable end brick chimney stack. Both the farmhouse and outhouse form an important group, which together with a number of other outbuildings are located in an isolated position in Upgate Green which lies to the south of the main settlement of Shotesham. There are views of the buildings when travelling along the adjoining road, together with views looking towards the north where they form the backdrop across the open farmland. This rural, undeveloped and gently undulating landscape has important historic associations with these buildings as the surrounding farmland and this setting positively contributes to their significance.

140-143: Setting of farmhouse and outbuilding from the adjoining road

144 & 145: View looking south along Brooke Road adjacent to the farmhouse and open farmland immediately to the south

146 & 147: View looking north towards farmhouse across open farmland and view to south along Brooke Road

4.15 **Site 9**: There are 4 Grade II listed buildings in close proximity including Waterfield Cottage to the north-west of site 9, Oldhouse Farmhouse and the Barn at Oldhouse Farm to the west of site 9 and Littlebeck Farmhouse to the south-east of site 9. The Brooke and Kirstead Conservation Area also lies to the north and east of site 9.

4.15.1 **Waterfield Cottage, Brooke** is a Grade II listed, timber framed, brick and rendered house with a thatched roof, originating from the early 17th century. A further cell was added in the late 17th century, leaded casements date from the 18th century, with further alterations and extensions in the 20th century. Two eyebrow dormers have Gothick leaded casements and the brick axial chimney stack is 17th century. The building is set back from the road and occupies a relatively secluded position being surrounded by hedges and mature trees with only glimpses of the building when passing the entrance drive and its setting therefore being tightly defined.

148 & 149: View of Waterfield Cottage looking west and access driveway from High Green with building set back from the road

4.15.2 **Oldhouse Farmhouse, Brooke** is a Grade II listed, early 17th century farmhouse with later alterations. It has a gabled clay pantile roof, English bond brickwork and render to the front, with a timber framed cross-wing to the south faced in Flemish bond brickwork during the mid-19th century. Key architectural features which contribute to its significance include moulded brick kneelers to coped gables, 17th century brick axial chimney stack with moulded bases to 4 octagonal brick shafts, casement windows with glazing bars and a 3-unit lobby-entrance plan form with parlour in cross wing and a stair turret to the rear. Immediately to the south is the **Barn at Oldhouse Farm, Brooke**, which is separately listed Grade II. This also dates from the 17th century and is timber framed and weatherboarded with a corrugated iron roof. It has a 4-bay plan with a gabled projection to the south, a later brick extension to the east, arched braces to tie beams and curved wind braces to the upper purlins. The farmhouse and adjacent barn are also listed for group value, forming and important historic group. The key views of the farmhouse and barn are mainly appreciated from the adjacent road looking towards the west where there are open views of the principal façade of the farmhouse and the gable of the barn and adjacent yard. Open farmland surrounds the properties particularly to the east and to the south and there are views across this area towards the buildings looking west. There are important historic connections between these buildings and the surrounding farmland and this setting positively contributes to an understanding of their historic function and the overall significance of the buildings.

150-153: Setting of farmhouse and adjacent barn in views to west from the road

154-155: Open farmland looking east and view to the west across open farmland toward the farmhouse and barn

4.15.3 **Littlebeck Farmhouse, Brooke** is a Grade II listed house dating from the early 19th century with a 17th century wing to the rear. Built of brick and a rendered timber frame, it has a hipped, black glazed pantile roof. Key architectural features contributing to its significance include a symmetrical façade with 16 pane sash windows, a central porch with pilasters and a moulded flat hood, 6 panel door, brick cornice, 2 chimney stacks to the rear wall and a large central axial chimney stack to the rear with 17th century brickwork to the lower courses. It has a 19th century, 3-cell

plan form and a 17th century 2-cell lobby entrance type plan to the rear wing. The main façade of the building faces east and there are views of the building from the adjacent track, where it is set back from the surrounding hedge, with the building mainly being seen through the entrance driveways. There are further buildings immediately to the north as well as along the opposite side of the track in a linear pattern. The building is surrounded by open areas of farmland and there are views across this looking to the east where the rear (earlier) wing of the farmhouse along with the chimneys and roof are seen amongst the trees, with the degree of visibility increasing during the winter. The farmhouse has historic associations with the surrounding farmland and this open undeveloped setting positively contributes to its overall significance.

156 & 157: Setting of the farmhouse with its principal façade being visible in views towards the west from the adjoining track

158 & 159: View to the east across open farmland with the farmhouse visible through surrounding trees and view to the east along Littlebeck Lane through open farmland with the farmhouse visible in the background

4.15.4 **Brooke and Kirstead Conservation Area**, originally designated in 1975, lies to the north and east of site 9. The Conservation Area has four distinct character areas with the historic linear south-west to north-east settlement along High Green being

closest to the north of site 9. This area has a number of historic buildings including the Victorian school and a number of red brick cottages on the south side of High Green. The Conservation Area lies within a relatively flat plateau and there are several views towards the settlement from the surrounding fields. However, much of the development is interspersed with verdant landscaping and tree belts around the settlement and as a consequence, views of buildings within the area from the open countryside are limited. The Conservation Area does however retain a rural backdrop of agricultural fields, with the boundary backing on to open countryside all along the south side of the village.

160 & 161: Views to the north across open farmland towards High Green within the Brooke and Kirstead Conservation Area

4.16 **Site 10**: There are 3 Grade II listed buildings in close proximity, including the Old Rectory, Beulah House and Beulah Barn, all to the west of site 10B. In addition, Seething Conservation Area lies to the north of site 10E and although it has been scoped out of further assessment in the Heritage Statement submitted with the application, it has been included because it is potentially affected by the proposed development.

4.16.1 **Old Rectory, Woodton**, is a Grade II listed, colour washed brick and timber framed house with hipped slate and tile roofs, comprising a 19th century 3-cell range and a 17th century 2-cell range to the rear. The south façade has a central doorcase, 6-panel door, sash windows with glazing bars, a 19th century bay window and a 20th century glazed conservatory. The rear range has brick to the ground floor and plaster to the first floor, casement windows with glazing bars, timber porch with plank door, a canted bay window, axial chimney stack and a brick gable wall to the north. The building is set back on the east side of Norwich Road and is surrounded by mature trees and vegetation, although there are some views through the trees with the degree of visibility increasing during the winter. There are a number of other buildings immediately to the north with open land to the south and east. To the north there is an track with views towards the building looking west, although there is very limited visibility of the building which is largely obscured by surrounding mature trees.

162 & 163: Views of the Old Rectory seen through surrounding mature trees looking east from Norwich Road

164 & 165: Views from the track looking west towards the Old Rectory which is largely obscured by surrounding mature trees

4.16.2 **Beulah House, Woodton**, is a Grade II listed 19th century brick house with a slate roof comprising 2 parallel 3-cell ranges. The west facing formal façade has sash windows with glazing bars and a central 6 panel door with fanlight. The rear east façade also has a formal composition with sash windows with glazing bars and a central door. The end brick gables have parapets and brick chimney stacks. Beulah House sits on the east side of the main Norwich Road and is set back beyond a low brick boundary wall. Although surrounded by mature trees and vegetation there are glimpses of the principal façade in views towards the east when travelling along the road, with the building being more visible during the winter. Immediately to the east is open farmland and there are views of the house towards the west across this open land, particularly from the track to the south. There is further open farmland to the east on rising and gently undulating ground, which forms the backdrop in views to the east from the house.

166 & 167: Views to the north-west across adjoining open farmland

168 & 169: View looking east along the track which runs to the south of Beulah House through open farmland with rising and undulating farmland beyond and wider view looking north-west towards Beulah House across open farmland

4.16.3 **Beulah Barn, Woodton** is a Grade II listed former threshing barn dating from circa 1600. It is a timber framed four-stead barn on a brick plinth, weatherboarded with a steeply pitched pantile roof and a gabled wing to the east forming an L-shaped plan. There are large double waggon entrance doors to the west wall and later double doors and window opening to the south gable. The wing to the east has catslide extensions to the north and south sides. Beulah Barn is located to the east of the main Norwich Road and to the north of Beulah House. Although surrounded by mature trees and vegetation there are views of the gable and roof of the barn from the road. Immediately to the north and east is open farmland and there are views of the barn towards the west across this open land, particularly from the track to the south, where it can also be seen along with Beulah House. There is further open farmland to the east on rising and gently undulating ground, which forms the backdrop in views to the east from the barn.

170 & 171: View of Beulah Barn to the north-west and together with Beulah House across adjoining open farmland

172 & 173: Wider view to the north-west from the track to the south and view to the east across open farmland with rising and undulating farmland beyond

4.16.4 **Seething Conservation Area**, designated in 1994, lies to the north of site 10E. Key characteristics include:

- Linear settlement based on rural agricultural economy
- Picturesque mere at the centre of village with Mere House facing the pond to the west
- Partially moated village church with triangular green to south

Seething is surrounded by relatively flat agricultural land and as a consequence, some buildings within the settlement can be viewed from some distance away. However, the extent of mature trees and vegetation means that there are partial glimpses into the area from surrounding fields. The village has not been extended with any large scale suburban or estate type development and therefore, its linear characteristics are well preserved, with the Conservation Area including most of the settlement.

174 & 175: Views looking north across open farmland where buildings mark the start of Seething Conservation Area

176 & 177: Views across open farmland looking north towards the Conservation Area and to the south from the Conservation Area

5.0 Relevant Legislation, Policies and Guidance

5.1 In relation to heritage assets the following policies and guidance are considered to be relevant when assessing the proposed development of the site :

5.2 **Overarching National Policy Statement for Energy (EN-1)** 2025 and **National Policy Statement for Renewable Energy Infrastructure (EN-3)** 2025

5.3 **National Planning Practice Guidance : Historic environment** (updated July 2019) sets out the main legislative framework for planning and the historic environment and states : *'Any decisions where listed buildings and their settings and conservation areas are a factor must address the statutory considerations of the Planning (Listed Buildings and Conservation Areas) Act 1990 (see in particular sections 66 and 72) as well as applying the relevant policies within the development plan and the National Planning Policy Framework.'*

5.4 **Section 66(1)** of the **Planning (Listed Buildings and Conservation Areas) Act 1990** states *'In considering whether to grant planning permission for development which affects a listed building or its setting, the local planning authority or as the case may be, the Secretary of State, shall have regard to the desirability of preserving the building or its setting or any features of special architectural or historic interest which it possesses'.*

5.5 **Section 72** of the **Planning (Listed Buildings and Conservation Areas) Act 1990** imposes a general duty on local planning authorities in relation to the exercise of planning functions affecting Conservation Areas which requires special attention to be paid to the desirability of preserving or enhancing the character or appearance of that area.

5.6 **National Planning Policy Framework**, (revised August 2026), Section 20 : Conserving & enhancing the historic environment.

5.7 **Conservation Principles, Policies and Guidance : Historic England,** (April 2008).

5.8 **Historic England Guidance : Historic Environment Good Practice Advice in Planning : GPA2 'Managing Significance in Decision-Taking in the Historic Environment'** (July 2015) and **GPA3 'The Setting of Heritage Assets'** (Dec 2017).

5.9 **Historic England Advice Note 12 'Statements of Heritage Significance : Analysing Significance in Heritage Assets'** (October 2019).

5.10 **Greater Norwich Local Plan,** March 2024

5.11 **Neighbourhood Plans**

6.0 Assessment of the heritage impact of the proposed development

6.1 Section 5.9 of the Overarching National Policy Statement for Energy (EN-1) sets out policy details in relation to the historic environment, with paragraphs 5.9.11 – 5.9.17 referring to applicant assessment, paragraphs 5.9.18 – 5.9.22 referring to mitigation and paragraphs 5.9.23 – 5.9.37 referring to Secretary of State decision making.

6.2 Paragraph 5.9.11 states that consideration needs to be given to the possible impacts, including cumulative, on the wider historic environment and paragraph 5.9.14 requires the applicant to *'ensure that the extent of the impact of the proposed development on the significance of any heritage assets affected can be adequately understood from the application and supporting documents.'*

6.3 Paragraph 5.9.28 states that: *'When considering the impact of a proposed development on the significance of a designated heritage asset, the Secretary of State should give great weight to the asset's conservation. The more important the asset, the greater the weight should be. This is irrespective of whether any potential harm amounts to substantial harm, total loss, or less than substantial harm to its significance.'*

6.4 Paragraph 5.9.29 states that: *'The Secretary of State should give considerable importance and weight to the desirability of preserving all heritage assets. Any harm or loss of significance of a designated heritage asset (from its alteration or destruction, or from development within its setting) should require clear and convincing justification.'*

6.5 Paragraph 5.9.33 states that: *' Where the proposed development will lead to less than substantial harm to the significance of the designated heritage asset, this harm should be weighed against the public benefits of the proposal, including, where appropriate securing its optimum viable use.'*

6.6 Paragraph 5.9.37 states that: *'When considering applications for development affecting the setting of a designated heritage asset, the Secretary of State should give appropriate weight to the desirability of preserving the setting of such assets and treat favourably applications that preserve those elements of the setting that make a positive contribution to, or better reveal the significance of the asset. When considering applications that do not do this, the Secretary of State should give great weight to any negative effects, when weighing them against the wider benefits of the application, The greater the negative impact on the significance of the designated heritage asset, the greater the benefits that will be needed to justify approval.'*

6.7 The third stage of the Historic England Guidance is to assess the effects of the proposed development, whether beneficial or harmful, on the significance or the ability to appreciate it. The assessment should address those attributes relevant to the proposed development from the following checklist:

Assessment Step 3 Checklist

The following is a (non-exhaustive) check-list of the potential attributes of a development affecting setting that may help to elucidate its implications for the significance of the heritage asset. It may be that only a limited selection of these is likely to be particularly important in terms of any particular development.

Location and siting of development
- Proximity to asset
- Position in relation to relevant topography and watercourses
- Position in relation to key views to, from and across
- Orientation
- Degree to which location will physically or visually isolate asset

Form and appearance of development
- Prominence, dominance, or conspicuousness
- Competition with or distraction from the asset
- Dimensions, scale and massing
- Proportions
- Visual permeability (extent to which it can be seen through), reflectivity
- Materials (texture, colour, reflectiveness, etc)
- Architectural and landscape style and/or design
- Introduction of movement or activity
- Diurnal or seasonal change

Wider effects of the development
- Change to built surroundings and spaces
- Change to skyline, silhouette
- Noise, odour, vibration, dust, etc
- Lighting effects and 'light spill'
- Change to general character (eg urbanising or industrialising)
- Changes to public access, use or amenity
- Changes to land use, land cover, tree cover
- Changes to communications/accessibility/permeability, including traffic, road junctions and car-parking, etc
- Changes to ownership arrangements (fragmentation/permitted development/etc)
- Economic viability

Permanence of the development
- Anticipated lifetime/temporariness
- Recurrence
- Reversibility

178: Step 3 Checklist, Historic England GPA3 'The setting of heritage assets'

6.8 The assessment of significance undertaken in Section 4.0 of this report identifies a total of 45 listed buildings and 4 Conservation Areas where there is potential for the proposed built development to impact on their setting. An assessment now follows on a site by site basis, using the relevant criteria from the Historic England checklist as set out above, to determine the impact of the proposals and whether or not there will be any harm caused and if so, the degree of harm.

6.9 **Sites 1 and 2 and BESS** In addition to several areas of solar PV arrays proposed throughout various parcels of land, the north part of site 1B is the proposed location for the new National Grid Substation, along with associated overhead line works and a 400kV substation, and the proposed Battery Energy Storage System (BESS) with a 400kV substation to the south.

6.10 **Broadgate Way** is in close proximity to the proposed site which lies to the east. It sits in a relatively isolated location with mature trees and vegetation providing a degree of seclusion with open views across the land to the west. Although the

surrounding open agricultural land contributes to its overall significance, there is limited intervisibility with the site to the east and it is therefore agreed that there will be no harmful impact on the significance of Broadgate Way.

6.11 **Moulton Farmhouse** sits in an isolated location with surrounding open farmland forming its setting and making an important contribution to its significance. The principal façade of the farmhouse faces west and there are several important open views both from and towards the site where the building is experienced in its rural, agricultural setting, particularly to the west, north-west and south-west, as illustrated in photographs 17-22. Although the existing field immediately to the west is to remain undeveloped the proposed solar panels are to be located in the adjoining field to the west, in relatively close proximity to the farmhouse where there are currently open views. In addition, the proposed National Grid Substation and a 400kV substation are to be located to the north-west of the farmhouse and the BESS and a 400kV project substation to the south-west. The submitted impact assessment acknowledges that the solar PV arrays and the project substation will be visible to the west of Moulton Farmhouse and views of the farmhouse from the public footpath will be largely obscured by the proposed substation. Although it is intended to plant a native linear tree belt along the boundary of sub-site 1B to restrict views once matured (after approximately 15 years), the impact assessment concludes in Paragraph 4.44, that the proposals will result in less than substantial harm to the significance of Moulton Farmhouse, although at the lower end of the scale. However, taking account of the height of the proposed panels and their proximity to the farmhouse, additional planting is unlikely to effectively screen them from view, thereby introducing incongruous and industrial features within its setting. Furthermore, the proposed mitigation measures will in themselves have an adverse impact by severing the historic visual relationship between the farmhouse and the open character of the surrounding landscape. It is therefore agreed that although there will be an adverse impact which is considered to be less than substantial, this will be at a higher level of moderate harm.

6.12 **Laurels Farmhouse** and **Barn to the east** are mainly appreciated in views from High Green, although being set back from the street and surrounded by mature trees and vegetation they are relatively secluded. However, there are open views from the buildings to the south and towards the buildings looking north across open farmland which forms their setting (see photos 26 & 27). Although the land immediately to the south is to remain undeveloped, the area beyond is to include both solar panels and a substation, in addition to the proposed National Grid Substation to the south-west. The submitted impact assessment notes that their rural setting contributes to their significance, but concludes at Paragraphs 4.45 and 4.46 that there will be no harm to the significance of the farmhouse or the barn. However, there is no assessment of the degree of visibility or impact of the proposed National Grid Substation, particularly in views to the west and to the north where it will form the backdrop across open farmland in conjunction with the farmhouse and barn. The solar panels will also be seen along

the horizon in these views although visibility will be reduced after the proposed planting has matured (approx. 15 years). It is therefore concluded that there will be some degree of harm which is considered to be less than substantial at the lower end of the scale.

6.13 **Hill House** is a prominent three-storey building with its principal façade facing west and is surrounded by flat areas of farmland which form its setting with key views both to and from the building to the north and south and across open land to the west. Solar panels are proposed in sub-site 2A, immediately to the west, setback only 20m from the road, in close proximity to the building. The submitted impact assessment notes that the panels will be effectively screened by tree and hedgerow planting, once matured, after a period of approximately 15 years and concludes in Paragraph 4.49 that although there will be minor changes to its setting, there will be no noticeable impact on the significance of the building or the ability to appreciate it and there will be no harm resulting from the scheme. Paragraph 4.48 also states that *'Setbacks incorporated into the design of the scheme, combined with the proposed landscape mitigation, will ensure that the roadside prominence of the designated heritage asset is preserved and that the presence of solar PV arrays will not distract from views and therein appreciation of the listed building'.* On the contrary, it is considered that the addition of 4.5 m high solar PV arrays in close proximity to Hill House, will result in alien and industrial features being clearly visible within its existing open setting. Furthermore, the proposed mitigation measures, which will not create any effective means of screening for several years, will in themselves have an adverse impact by creating a sense of enclosure and severing the visual relationship between Hill House and the surrounding open and undeveloped landscape. Important views towards the building, such as those from the west from public footpaths, where it is appreciated in an open, rural landscape setting, will also be blocked. In addition, views from the building towards the west, particularly from the upper floors, which are currently open and rural in character, will change to an industrial landscape dominated by solar panels. It is therefore concluded that there will be a harmful impact on the significance of Hill House arising from the proposed development of sub-site 2A, which is considered to be less than substantial, but at a moderate level.

6.14 **French's Farmhouse** is part of an isolated farmstead with associated outbuildings and is relatively secluded being enclosed by mature trees and vegetation, but is appreciated in several glimpsed views from the extensive, surrounding flat and open farmland which forms its setting. Solar PV arrays are proposed on sub-sites 2B and 2C some distance away to the west of the farmhouse on the opposite side of the A140. Although there will initially be some visibility of the panels along the horizon in views towards the west, this will be screened by the proposed landscaping mitigation measures once matured. Taking into account the distance between the proposed panels and the farmhouse, it is agreed that there will be no harmful impact on the significance of French's Farmhouse.

6.15 **Barn Cottages** are a pair of cottages in a fairly isolated location surrounded by open farmland and are appreciated in many views as illustrated in photos 32-38, particularly towards the south where the main façade is seen, as well as to the north and west from Station Road. The proposed BESS and 400kV substation are to be located within site 1, around 280m to the north of Barn Cottages.

6.16 Paragraphs 4.52 and 4.53 of the submitted impact assessment state *'The listed building is set back from the frontage of Station Road which, on the opposing side, there is an intervening range of two-storey cottages that effectively block intervisibility between Barn Cottages and the site'* and *'It is not thought likely that built elements of the scheme will be visible from Barn Cottages due to its position, particularly if they are located within the eastern part of the BESS site. However, if located at the western limit of the BESS site, visibility analysis would suggest that taller elements of the Project Substation may be visible from the listed building although these views would be restricted to a small section of the sub-site, be oblique and largely obscured by the property situated to the north'.*

6.17 Paragraph 4.55 goes on to say *'However, when travelling northwards along Station Road and to the south-east of Barn Cottages, both the listed building and 400kV substation would be visible. The substation would be at a sufficient distance so as not to be prominent in this view, but would certainly be another element in the landscape included in this wider ranging vista of Barn Cottages. Landscaping initiatives as part of the scheme will include tree planting along the southern boundary of site 1, which will obscure intervisibility with the substation once matured. This is however, expected to take an estimated period of 30 years for the new woodland to reach sufficient height to screen the substation'* and Paragraph 4.65 *'The wider setting of the listed building is overwhelmingly rural, but not exclusively as there are several industrial buildings, including a large maltings, visible to the west of the cottages and the numerous pylons that dot the surrounding landscape. The BESS, noise barrier screening and substation would introduce another industrial looking element to this wider landscape setting but would not be overall incongruous due to the presence of other more industrial structures in the vicinity, albeit not a large number of these. The setting of Barn Cottages provides a minor contribution to its significance in the emphasis of its traditional, rural architecture but does not inform the significance to any major degree. Views best illustrating the rural surroundings are to the south and these will be unaffected by the scheme'.*

6.18 The impact assessment concludes at Paragraph 4.57 that *'The Project Substation will be situated to the south of the BESS within the BESS sub-site. It is considered that, depending on the exact final solution of the Project Substation within this area, there will be either no or oblique, partial views of taller elements of the structure from the listed building itself. In the latter case, this would result in a minor adverse effect resulting from some change to the heritage asset's setting, but not to a degree that it would materially compromise the significance of the heritage asset. It is*

considered that this change has the potential to cause less than substantial harm at the lower end of the scale, reducing to no harm once the landscape screening has matured'.

6.19 The approach to the assessment of the impact of the proposals, as set out above, together with the conclusions reached, raise a number of concerns:

- The impact of the proposed substation and the BESS on the significance of Barn Cottages cannot be fully assessed without further information including such details as scale and height; details of proposed built structures, plant and equipment; noise barrier screening; boundary treatment and enclosures; materials etc.
- The assessment makes reference to the existence of other industrial type buildings and structures within the setting of Barn Cottages, in particular the maltings to the west. However, they are located some considerable distance away on the other side of the railway line, being largely screened by mature trees with very little intervisibility between the cottages and the maltings. Nevertheless, the existence of any industrial type structures is not considered to be a valid reason to introduce further incongruous structures in much closer proximity to the cottages, which would have a harmful impact on their significance, by eroding the distinctive and predominantly rural and agricultural character of their setting.
- The assessment states that the setting of Barn Cottages provides a minor contribution to their significance, emphasising their traditional rural architecture, but does not inform their significance to any major degree. However, it is important to note that, with the exception of the small terrace of cottages on the opposite side of the road, their setting has historically remained open and undeveloped. Furthermore, there are historic associations between the cottages and use of the surrounding land and the likelihood of occupants working as part of the local farming community. It is therefore considered that the open, rural farmland setting of Barn Cottages makes a very positive and important contribution to their overall significance as a locally distinctive, vernacular building of simple form, traditional materials and details.
- The assessment of setting focusses on views to the south and concludes that they best illustrate the rural surroundings of the cottages and that they will be unaffected by the scheme. However, the setting of a heritage asset is dynamic and the relationship with its surroundings changes as one moves around, rather than being defined by a single viewpoint. The siting of the cottages within the open surrounding landscape and the twisting and winding nature of the B1134 Station Road mean that the building is experienced within this setting in numerous views and from several different angles. The cottages on the opposite side of the road are unlikely to provide effective

screening of the proposed works as claimed, with the development being visible along with Barn Cottages from many viewpoints along Station Road. The proposed substation and BESS will introduce potentially visually dominant, alien and incongruous industrial features, into an open and undeveloped rural landscape.

6.20 In conclusion therefore it is agreed that the proposals will have a harmful impact on the significance of Barn Cottages which will be less than substantial. However, on the basis of the limited information provided and taking into account the points raised in the preceding paragraph, this harm is likely to be at a higher level of moderate rather than low.

6.21 **Site 3** proposes several areas of solar PV arrays on a number of parcels of land. The three listed buildings on the north side of the street, **Rose Cottage**, **Three Feathers** and the adjacent **Barn and Stable Range** are all experienced in views looking to the north from the street. Although there are some limited and restricted views of the site towards the south from these buildings, mainly from Rose Cottage, it is agreed that the existing open farmland does not contribute to their overall significance and there will be no adverse impact arising from the proposed development of site 3.

6.22 **Townhouse Farmhouse** is located on the south side of the street and there are long, distant and open views towards the site both from the farmhouse and in conjunction with the farmhouse looking from the street. This open, undeveloped farmland forms the wider setting of the farmhouse and there are historic associations between the use of the land and the farmstead. The submitted impact assessment concludes that there will be no harm to the significance of Townhouse Farmhouse arising from the proposed development of site 3. However, even though the field immediately to the south of the farmhouse is to remain open, without any built development or landscaping and the proposed solar PV arrays are some distance away, taking account of their height, movement and potential glare, they will be visible and form the backdrop in views to the south. Furthermore, although some linear planting is proposed, this will not effectively screen visibility of the panels for a number of years until well established with some degree of visibility remaining during the winter months. The panels will introduce an alien and industrial feature into this agricultural landscape setting which has remained undeveloped over time. It is therefore concluded that there will be some harmful impact on the significance of Townhouse Farmhouse which is considered to be less than substantial at the bottom end of the scale.

6.23 **Site 4** includes several areas of solar PV arrays on a number of parcels of land within site 4A to the west of the A140 and site 4B to the east, along with a 132kV substation within site 4B.

6.24 The Grade I listed **Church of St Michael** and the Grade II* listed **Old Rectory** are high status buildings which, together with the Grade II listed **Barn to the north**, form an important group. The submitted heritage statement acknowledges at Paragraph 6.17 that the rural setting adds to the significance of the Church which has served a small, agricultural community for hundreds of years, at Paragraph 6.21 that the Old Rectory also derives significance from its historic interrelationship and therefore, group value with the Church and Barn to the north and at Paragraph 6.25 that the setting of the Barn is rural with views overlooking the surrounding countryside reinforcing its agricultural character. However, the submitted impact assessment concludes in Paragraphs 6.61 to 6.63 that there will be no harm to the significance of the Church, the Old Rectory or the Barn to the north, principally as a consequence of the retention of the south portion of site 4B, located closest to these buildings, as open land without any development. It also notes in Paragraph 6.61 that *'The remainder of site 4 does not contribute in any meaningful way to the church's setting and the diminishing effects of distance would mean that any remaining views of solar PV arrays would be both very limited and small elements of wider vistas.'*

6.25 A detailed assessment of the setting of this important group of buildings shows that there are views looking north towards the site from the Church and from several viewpoints within the churchyard where the surrounding open farmland is visible, often in conjunction with the Church and the Barn. There are also views looking south from the site where the Barn and Church tower are clear features within the landscape, with the degree of visibility to and from the open surrounding land being greater in the winter months. These views are illustrated in photographs 47, 50 & 51, and 56-58 within this document. In addition, although there has been some negative impact on the setting of the group arising from the recent construction of the Long Stratton bypass to the south, the new footbridge and footpath have opened up panoramic views towards the north and north-east where this group of buildings can be appreciated in the surrounding open, rural landscape which forms their setting. In these views all three buildings can be seen together, as illustrated in photograph 49 of this document. A 132kV substation is also proposed within site 4B, located to the north of this group of buildings. In the absence of full details of the proposed substation including plant, equipment, boundary treatment etc., there is inadequate assessment of the impact of this part of the development, particularly visibility from in wider views and from within the churchyard. Although set back within the site, taking account of the height, scale and movement of the proposed solar panels, along with the substation and associated equipment, they will introduce alien and industrial features, as a continuous addition along the horizon, forming the backdrop in views towards the north and north-west, across the open land in the foreground. They will also be seen in views from within the churchyard, with visibility and prominence increasing during the winter months Given the high status of these buildings and the important contribution that this rural setting makes to their significance, with the land historically remaining open and undeveloped, it is therefore concluded that there will be some degree of harm to the significance of

the Church, the Old Rectory and the Barn, which is considered to be less than substantial at a moderate level.

6.26 The **Cottage occupied by** [redacted] (now known as Thatched Cottage), is relatively isolated with its rural setting defined by the surrounding open and undeveloped landscape, making an important contribution to its significance. The submitted impact assessment concludes at Paragraph 6.64 that *'As the southern fields of sub-site 4B are not allocated for built elements under the scheme and rather will be planted with new grassland. This does not have the potential to impact the ability to appreciate the significance of the cottage and there will be no harm to the listed building'.* However, there are several wide views to the north, including from the new footbridge, where the surrounding open agricultural land including the proposed site, forms is setting, along with views to the south from the site, where the cottage is seen in an open rural landscape setting, as illustrated in photographs 59, 60, 62 and 63 of this document. Although some distance away, the proposed solar panels and substation will form the backdrop to these views, seen across the open land in the foreground in conjunction with the cottage, as incongruous features in the landscape. It is therefore concluded that this will result in a degree of harm to the significance of the cottage which is considered to be less than substantial, although at the lowest level of the scale.

6.27 **Church Farmhouse** occupies a secluded position being largely screened by mature trees and vegetation and surrounding ancillary farm buildings, with no views between the farmhouse and the proposed development site. It is agreed that the existing open farmland does not contribute to the overall significance of the farmhouse and there will be no adverse impact arising from the proposed development of site 4.

6.28 Although **The Cedars** and the cluster of adjoining buildings are set amongst mature trees, the open character of the surrounding land forms its wider setting and positively contributes to its overall significance, having historically remained undeveloped. Paragraphs 6.66 and 6.67 of the submitted impact assessment conclude that *'there will be no harm to the heritage asset mainly due to limited intervisibility and the retention of open land immediately to the east'.* However, as a three-storey building, The Cedars is a prominent feature in the landscape and although surrounded by mature trees it is clearly visible in many views. These include views to the east and north-east from the land on the west side of the A140; views travelling along the A140, particularly in a southerly direction, where it is seen within the open landscape setting, which adjoins to the west; views to the north from Church Lane, where the original, 17th century two-storey house is visible and views to the west across open land (see photos 66-69). Solar panels are proposed on existing open and undeveloped land to the north and east of The Cedars and either side of the A140 to the north-east and north-west. Taking account of the height of the solar panels, they will be visible in several of these views which form the setting of The Cedars, introducing incongruous and industrial features visible alongside the building. In

addition, as a three-storey building, there are views from The Cedars, particularly from the upper floors across the surrounding landscape which is predominantly open and rural in character. In views to the west, north and east this will change to an industrial landscape dominated by solar panels. It is therefore concluded that this will result in a degree of harm to the significance of The Cedars which is considered to be less than substantial, although at the lower level of the scale.

6.29 The **Pair of Houses owned by** [redacted] are mainly appreciated in views towards the north from Church Lane, with the surrounding open agricultural land to the east forming their setting. Paragraph 6.68 of the submitted impact assessment states that *'Intervisibility between site 4 and the listed building are limited to a small section at the south-eastern extent of sub-site 4B and the upper storey of the gable end. The only changes that will be made to these views will be the removal of intensive farming and new grasslands planted. As such, there will be no harm to the heritage asset'.* However, there is a greater degree of intervisibility, with long views from Church Lane to the north and north-east towards the surrounding open land which forms the setting of the pair of houses (see photos 71 & 72), as well as views from the area where solar panels are proposed looking south west with the houses being visible across open land (see photo 73) and the degree of intervisibility increasing in the winter months. Although some distance away, the proposed solar panels and substation will form the backdrop in views to the north and north-west in particular, seen across the open land in the foreground in conjunction with the pair of houses, as incongruous features in the landscape. It is therefore concluded that this will result in a degree of harm to their significance, which is considered to be less than substantial, although at the lowest level of the scale.

6.30 The **Cottage occupied by** [redacted] (Well Meadow Cottage) is located in a secluded position behind the pair of cottages on Church Lane. Although there are likely to be historic associations between the occupants of the cottage and the use of the surrounding land for agricultural purposes, there is very limited intervisibility between the two with only distant glimpses of the roof in views to the west across the open land. Taking this into account along with the distance between the proposed solar panels and the cottage, it is agreed that there will be no adverse impact on its significance arising from the proposed development of site 4.

6.31 **The Hollies** is located in a relatively isolated position to the east of site 4 surrounded by mature trees and hedges with the surrounding agricultural landscape forming its wider setting. Intervisibility between the house and the site is restricted due to existing trees and vegetation, with only the roof being seen in distant views to the east from the site. Taking account of the distance between the house and the proposed location of the solar panels and the degree of screening from existing mature vegetation, it is agreed that there will be no adverse impact on the significance of The Cedars arising from the proposed development of site 4.

6.32 **Site 5** proposes several areas of solar PV arrays on a number of parcels of land within sites 5A and 5B, along with a 400kV substation within site 5A. **Church Farmhouse** and the **Barn to the north-east** form an important group, located on the east side of The Street and are mainly experienced in views looking towards the east from the adjoining road. However, they are surrounded by open farmland which has remained undeveloped over time and there are historic associations between the use of the land and the farm buildings. This forms their wider setting and positively contributes to their overall significance, particularly in views to the north and south when travelling along The Street. The submitted impact assessment concludes that there will be no harm to the significance of either the farmhouse or the barn arising from the proposed development of site 5 and states in Paragraph 7.30 of the heritage statement that *'the only elements of the scheme that will be visible from Church Farmhouse and Barn would be the proposed community space. This will result in no harm to either listed building'*. However, although the field immediately to the west is to remain open and undeveloped, the land beyond, where PV arrays are proposed rises further towards the west and in addition, a large area of land to the north-west is allocated for the construction of a 400kV substation. In the absence of full details of the proposed substation including plant, equipment, boundary treatment etc., there is inadequate assessment of the impact of this part of the development, particularly visibility on the skyline. Historically, this land has remained open and undeveloped and forms the wider setting of the farmhouse and barn. The addition of solar panels taking account of their scale, height and movement along with the substation and associated equipment, will introduce alien and industrial features, forming the backdrop in views towards the west and north-west, with visibility and prominence increasing during the winter months. It is therefore concluded that there will be some degree of harm to the significance of Church Farmhouse and Barn, which is considered to be less than substantial at the bottom end of the scale.

6.33 The Grade I listed **Church of St Catherine** is a high status building which adjoins the southern boundary of site 5. It occupies a remote and secluded position with a distinct sense of peace, tranquillity and isolation being experienced on arrival at the lychgate entrance as well as within the surrounding churchyard and along the track leading to the church from The Street. Its rural setting has remained unchanged for centuries and makes a very important and positive contribution to its overall significance, serving many generations of the local agricultural community. The submitted heritage statement acknowledges that this interrelationship between the church and its surrounding churchyard and the wider agricultural landscape contribute to its significance.

6.34 The impact assessment is set out in Paragraph 7.29 of the submitted heritage statement as follows *'Views to and from the Church of St Catherine from Site 5 are primarily limited to the southern portion of Sub-Site 5B, which is situated immediately to the north of the listed building. Under the Scheme, this area would be used for a*

community space and there will be no built elements of the solar farm within the church's immediate vicinity. This will help to ensure that the Scheme does not overwhelm or detract from the prominence of the church and its rural setting, especially on the approach along The Street where it will still be appreciated and understood. There may be limited, filtered views of the church from Sub-Site 5B, but no views vice versa. On this basis, it is considered that the Scheme would cause no harm to the significance of the building.

6.35 However, having fully assessed the setting of the church, contrary to the statement above, there are views looking north into site 5B both from the access track and from within the churchyard, along with views to the west and to the north-west looking out from the churchyard. Although these views are between surrounding trees and vegetation, they do provide an important visual connection with the surrounding open and undeveloped farmland from within the intimacy of the churchyard, which forms the distinctively rural setting of the church . These views can be seen in photographs 79-82 of this document. Furthermore, there is a considerably increased degree of intervisibility during the winter months, as illustrated in photographs 83-86. The Scheme proposes solar panels to the west and to the north-west of the churchyard and in addition, a large area of land to the north-west is allocated for the construction of a 400kw substation. In the absence of full details of the proposed substation including plant, equipment, boundary treatment etc, there is inadequate assessment of the impact of this part of the development, particularly visibility from within the churchyard. Also during the winter months there are glimpses of the church seen through the trees when travelling south along The Street, with open farmland forming its setting to the west. The proposed location of the solar panels on land to the west will mean that they are visible on the horizon alongside these views of the church. Taking account of the proximity of the solar panels along with their scale, height, and movement, they will introduce alien, incongruous and industrial features within the rural setting of the church. It is considered that any visual intrusion of solar panels or the substation and its associated equipment, either in conjunction with the church or seen from within the churchyard will result in a harmful impact. In addition, any background noise generated by the substation will adversely affect the existing sense of peace and tranquillity within the churchyard. The degree of harm is considered to be less than substantial, although given the high status of the church and the contribution of the undeveloped rural setting to its significance, this will be at a moderate to high level.

6.36 The northern boundary of the **Fritton Conservation Area** adjoins the south and east boundary of site 5, with the Church of St Catherine, Church Farmhouse and Barn all lying within the Conservation Area. The area is distinctly rural in character with buildings dispersed along the road and around the common. Beyond the boundaries, the area is surrounded by open and undeveloped farmland which forms the setting of the Conservation Area. The submitted impact assessment acknowledges that there

will be some intervisibility between built elements of the scheme and the Conservation Area and Paragraph 7.28 of the heritage statement concludes that *'The approach to the Conservation Area from The Street to the north will have slight changes in views, through the introduction of solar PV arrays, but these will be located at least 500m from the Conservation Area boundary itself and consequently the immediate approach will remain unchanged. There will be no impact on views or other elements of the Conservation Area's setting and it is considered that the scheme will cause no harm to the heritage asset'.* However, when travelling north along The Street and out of the Conservation Area, the solar panels and substation will form the backdrop in views towards the west and north-west and although some distance away, will introduce incongruous features into an otherwise undeveloped, rural and agricultural landscape. It is concluded therefore that this will cause a degree of harm to the setting of the Conservation Area, which is considered to be less than substantial at the bottom end of the scale.

6.37 **Site 6** will not now contain any solar infrastructure and will remain in use for farming and wildlife habitat management. As a consequence, it is therefore agreed that there will be no harmful impact on the significance of surrounding heritage assets. However, it is unclear whether the site will be used during the construction phase of the project and if so, what works are proposed such as any surface treatment, storage of materials and consequent vehicular movements etc. Further details are therefore required in order to fully assess any impact on nearby heritage assets.

6.38 **Sites 7A – 7C** propose several areas of solar PV arrays on a number of parcels of land

6.39 The **Countryman Public House** is a prominent building on the A140 Long Stratton Road with its wider setting to the east formed by the undulating and gently rising farmland of the Tas Rural River Valley. There are views to the east from the building towards site 7A where solar PV arrays are proposed as well as views from the site across open land towards the building to the west. Although there is likely to be some visibility of the solar panels in distant views, there are no historic connections between the use of the land and the building as a public house which is not considered to make any key contribution to its significance. It is therefore agreed that the proposed development will not have an adverse impact on its significance.

6.40 **Hill Farmhouse** has a prominent location at the junction of the A140 and Fairstead Lane. There are several ancillary farm buildings to the north and views to the east where the surrounding open and undulating farmland within the Tas Rural River Valley forms its setting. There are also views towards the west across the open farmland where the farmhouse and its ancillary buildings are appreciated within a rural landscape setting. A solar PV array is proposed on sub-site 7A on existing open land which rises to the east of Hill Farmhouse. Paragraph 9.43 of the submitted impact assessment states that *'There are no views of site 7A from Hill Farmhouse with views*

towards the farmhouse restricted to only its roofline from a limited range within sub-site 7A from where this does nothing to demonstrate the farmhouse's significance. It is considered that the scheme will cause no harm to the significance of Hill Farmhouse'. However, an assessment of the setting of Hill Farmhouse shows that there are views towards the east from the front of the building along the access driveway where the rising ground of site 7A can be seen in conjunction with the farmhouse and outbuildings (see photos 96 & 97) . As a consequence of historic associations between the farmhouse and this surrounding open agricultural land which forms its setting, this positively contributes to its overall significance. The solar panels will be visible on the skyline and taking account of their scale, height and movement will introduce incongruous, industrial features on land which form its setting. It is therefore concluded that this will cause harm to the significance of Hill Farmhouse which is considered to be less than substantial and the lower end of the scale.

6.41 **Tramp's Hall** and **Barn immediately east** are located in a secluded position, surrounded by mature trees and vegetation. The barn is seen in views along Fairstead Lane, but the hall is set well back within the site and is only glimpsed when passing the entrance driveway. There are distant views across open farmland towards the west where the roof of the barn is seen in the wider rural setting. However, there are no views towards site 7A from either of these buildings and it is agreed that the proposed development will not have an adverse impact on the significance of the hall or the adjacent barn.

6.42 The **Former Quaker Meeting House** occupies a secluded position on the south side of Fairstead Lane and is mainly appreciated in views from the entrance driveway on Quaker Lane. Although the proposed solar panels are in close proximity, it is only the roof that is visible in views towards the south which is seen against a backdrop of mature trees and it is agreed that the proposed development will not result in any adverse impact on its significance.

6.43 **Wood Farmhouse** is experienced within a wide, open landscape setting, particularly the open farmland to the north and south, which positively contributes to its significance due to the historic relationship between the use of this land and the traditional rural farmstead buildings. A solar PV array is proposed on site 7C on land to the north of Wood Farmhouse. Paragraph 9.49 of the submitted impact assessment states that *'due to the retention of the open farmland closest to the farmhouse, the solar panels will not be prominent within any views from or of Wood Farmhouse and they will not encroach into the immediate setting of the listed building'*. The assessment also states that *'the proposed planting in the form of woodland planting, grassland borders and linear screening between the listed building and the solar PV arrays will in the medium to long term, effectively remove any views of these elements from the heritage asset'* and concludes that *'the scheme will cause no harm to the significance of Wood Farmhouse'*. However, even though there is a degree of setback between the farmhouse and the proposed solar panels, taking account of their height

and movement, they will be visible on the horizon in views from, as well as towards, the farmhouse. Furthermore, the proposed mitigation measures in the form of planting, will not provide sufficient screening of the panels for a considerable number of years and more importantly, will have an adverse impact on the setting of the farmhouse by creating a sense of enclosure and severing the historic visual relationship with the open farmland beyond. It is therefore concluded that this will cause harm to the significance of Wood Farmhouse, which is considered to be less than substantial and the lower end of the scale.

6.44 **Grove Farmhouse** is also experienced in a rural agricultural setting with open farmland to the north and south, pond to the east and several attractive outbuildings to the north and west. A solar PV array is proposed on site 7C on land to the north of Grove Farmhouse, with the scheme being set back and adjoining land being retained as farmland. Paragraph 9.51 of the submitted impact assessment states: *'It is possible that solar PV arrays within sub-site 7C may be visible to the north-east of Grove Farmhouse. However, these views will be glimpsed between the existing plantation to the east and the new woodland planting to the north. There will be a buffer of new grassland to the east and north-east that, although not screening the solar PV arrays from view, will soften the prominence of any built elements within the scheme'.* Paragraph 9.52 states: *'There will be minor alterations to the setting of Grove Farmhouse through the presence of a small section of the scheme in views to the north-east of the property. The majority of views from and of the listed building will remain unchanged. Elements of the listed building's setting that inform its significance are generally limited to the immediate grounds of the farmhouse including its yard and associated structures, although the wider agricultural surroundings provide a connection to the historic and current context of the listed building as a farmhouse and do somewhat highlight the rural nature of the building's design and intended purpose. However, it is not considered that the wider setting informs the significance to any meaningful degree and the presence of a small section of the scheme in one wide vista from the property will not result in harm to the heritage asset's significance or the ability to appreciate this'.*

6.45 The setting of Grove Farmhouse is wide and positively contributes to its significance due to the historic relationship between the use of the surrounding land and the traditional rural farmstead buildings (see photos 104 – 109). Furthermore, it is important to emphasise that this has remained unchanged and undeveloped over time. The submitted assessment is therefore considered to have undervalued the contribution of the setting of Grove Farmhouse to its overall significance. Even though the open farmland closest to the farmhouse is to be retained, taking account of the height and movement of the proposed panels, visibility of such alien and industrial structures is considered to be harmful to its open agricultural setting. Reference is also made to new woodland planting to the north and such mitigation measures are also considered to be harmful by severing the historic visual relationship with the open

farmland beyond. It is therefore concluded that the proposed development within site 7C will cause harm to the significance of Grove Farmhouse, which is considered to be less than substantial and the lower end of the scale.

6.46 **Sites 7D – 7H** propose several areas of solar PV arrays on a number of parcels of land, along with a 132kV substation within site 7F. **Manor Cottage**, **Manor Farmhouse** and **Manor Farmhouse Barn** are located to the north of sites 7D and 7F, and form an important group of Grade II listed buildings at the west entrance to Saxlingham Green Conservation Area.

6.47 **Manor Cottage** located in a prominent corner position, is appreciated in many views to the south, west and north and as a former farmhouse there are historic associations with the open farmland which forms its setting to the south and positively contributes to its significance. There are open views across this farmland from the boundary of the cottage (see photo 115). Solar PV arrays are proposed on site 7D to the south and site 7F to the south-east. Paragraph 10.45 of the submitted impact assessment states *'Embedded mitigation in the form of setbacks will ensure there is no intervisibility between Manor Cottage and built elements of the scheme within sub-site 7D and beyond. The scheme will result in no harm to the listed building'.*

6.48 **Manor Farmhouse** is also located in a prominent corner position with key views of the building to the west and to the north-east with open farmland to the south forming its setting and the building being seen in views towards the north across the open landscape (see photo 119). Also a former farmhouse, there are historic associations between the building and the surrounding land which forms its setting, positively contributing to its significance. Solar PV arrays are proposed on site 7D to the south-west and site 7F to the south. Paragraph 10.43 of the submitted impact assessment states *'Although there is no intervisibility between site 7 and Manor Farmhouse, it is situated in close proximity to sub-site 7D. Due to this, setbacks have been included in the design of the scheme and the part of this sub-site closest to the listed building will remain as open land. The nearest built elements of the scheme (solar PV arrays) will be situated at a distance of nearly 300m to the south-west and will not encroach into the setting of the farmhouse. There will be no harm to Manor Farmhouse's significance'.*

6.49 **Manor Farmhouse Barn** adjoins the farmhouse and historically would have been part of the farmstead. Although occupying a slightly more secluded position there are views of the roof and gable end in views to the east and looking north from the open farmland, with visibility increasing during the winter months. Solar PV arrays are proposed on site 7D to the south-west and site 7F to the south. Paragraph 10.44 of the submitted impact assessment states *'The setbacks incorporated into the design of the scheme within sub-site 7D will ensure that no solar PV arrays or other built elements will be visible from the barn and there will be no impact on its setting.*

Therefore, it is considered that there will be no harm to the significance of the listed barn'.

6.50 Although the area of site 7D closest to Manor Cottage, Manor Farmhouse and Manor Farmhouse Barn is to remain undeveloped, the conclusions noted in paragraphs 6.47 to 6.49 above, focus on views towards the site looking south from these listed buildings. However, when they are approached towards the north along Broaden Lane, their setting is wide and open, with the buildings being visible on the horizon amongst surrounding trees and vegetation, with visibility increasing in the winter months. Taking account of the height and scale of the proposed solar panels, which are intended to be located immediately to the west of Broaden Lane, the ability to appreciate these buildings in their wide, open and undeveloped agricultural setting will be lost, being obscured by alien and industrial features in a rural landscape. Furthermore, paragraph 10.48 of the impact assessment refers to additional tree and hedgerow planting and concludes that once matured, built elements of the scheme within these sub-sites will be effectively screened from surrounding heritage assets. However, apart from taking a considerable number of years to effectively screen the solar panels, these mitigation measures in the form of planting will in themselves have an adverse impact by creating a sense of enclosure and severing the visual relationship between the buildings and their open setting. It is therefore concluded that the proposed development will have a harmful impact on the significance of Manor Cottage, Manor Farmhouse and Manor Farmhouse Barn, which is considered to be less than substantial at the lower end of the scale.

6.51 As a former farmhouse, **Hill Cottages** are mainly appreciated in views towards the east but they are also seen in views across open farmland to the west and to the south, which forms their wider setting (see photos 122-125). Solar PV arrays are proposed on site 7D to the south of the property. Paragraph 10.46 of the submitted impact assessment states *'Setbacks have been designed into the paraments of sub-site 7D and the northernmost field, in closest proximity to Hill Cottages, will not contain any solar PV arrays or other built elements. As such, there will be no visibility of any parts of the scheme beyond the new landscaping initiatives in this field and there will be no impact to the listed building's significance. There will be no harm to the listed building resulting from the scheme'.* Even though the area closest to Hill Cottages is to remain open and undeveloped, taking account of the height and movement of the solar panels, they will be visible in views along with the property, particularly to the south-west, introducing alien and industrial features within their rural agricultural setting. Any mitigation measures including tree and woodland planting will take a considerable number of years to effectively screen the solar panels and will also have a negative impact by creating enclosure and severing the visual relationship between the building and the surrounding open setting. It is therefore concluded that the proposed development will have a harmful impact on the significance of Hill Cottages, which is considered to be less than substantial at the lower end of the scale.

6.52 **Hill House** is slightly set back from the road with its chimneys and roof visible in views to the north (see photo 126). It is mainly appreciated from its setting to the west, with the surrounding open and undeveloped farmland to the south forming its wider setting. Although it is separated from areas of open farmland by adjacent buildings to the south, as the taller and more prominent structure, there is intervisibility between the building and the site of the proposed solar panels, with the degree of visibility increasing during the winter months. Paragraph 10.47 of the submitted impact assessment states that no built elements of the scheme will be visible from Hill House and that there will be no harm arising from the scheme on its significance. However, taking account of the height and movement of the solar panels, they will be seen in views from Hill House to the south and from the site in views to the north towards Hill House. introducing alien and industrial features within this rural agricultural setting. Any mitigation measures including tree and woodland planting will take a considerable number of years to effectively screen the solar panels and will also have a negative impact by creating enclosure and severing the visual relationship between the building and the surrounding open setting. It is therefore concluded that the proposed development will have a harmful impact on the significance of Hill House, which is considered to be less than substantial at the lower end of the scale.

6.53 **Holly Cottage** was scoped out of further assessment in the submitted heritage statement as it was considered that it would not be impacted by the proposed development. However, it is located at the east end of the Saxlingham Green Conservation Area in an open setting where it is set back from The Green with open and undeveloped farmland to the north and south forming its wider setting (see photos 127-130). Solar PV arrays are proposed on site 7F on existing open farmland to the south of Holly Cottage. There are panoramic open views looking west where this site is visible along with Holly Cottage with intervisibility between the two increasing during the winter months. Taking the height and movement of the proposed solar panels into account, they will introduce alien and industrial features as a visual intrusion into this rural setting. Mitigation measures including tree planting will take a considerable number of years to effectively screen the solar panels and will also have a negative impact by creating enclosure and severing the visual relationship between the building and the surrounding open setting. It is therefore concluded that the proposed development will have a harmful impact on the significance of Holly Cottage, which is considered to be less than substantial at the lower end of the scale.

6.54 **Saxlingham Green Conservation Area** has a distinctive green and rural character with a strong sense of intimacy and enclosure formed by mature trees and vegetation with occasional buildings scattered along the road or set back from the open green spaces. There are occasional open views, particularly out towards the south, from within the Conservation Area, which provide important visual connections with the open and undeveloped countryside which surrounds and forms the setting of the Conservation Area (see photos 131 & 132). Approaching the Conservation Area

from the south along Broaden Lane from Hempnall, there is a distinct change in character, from a strong sense of openness provided by undeveloped farmland, to a cluster of buildings which create a sense of arrival and define the west entrance to the Conservation Area (see photo 133). Paragraph 10.39 of the submitted impact assessment refers to the proposed mitigation measures and states that *'These proposed landscaping initiatives will ensure that the scheme does not encroach onto the setting of Saxlingham Green by obscuring it from views within the Conservation Area itself. This will therefore maintain the rural agricultural character and appearance of the Conservation Area. The woodland and grassland planting will improve the surrounding outlooks to the west of the Conservation Area and will render impacts to the setting as negligible, once matured'.* Paragraph 10.41 concludes that the scheme will cause no harm to the character and appearance, and/or significance, of Saxlingham Green Conservation Area. However, taking account of the height and location of the proposed solar panels within site 7D to the south-west of the Conservation Area, not only will the proposed planting take many years to provide any effective screening, but more importantly, it will sever the visual relationship between the Conservation Area and the open and undeveloped surrounding land which forms its setting and will result in the loss of the sense of arrival when approaching from the south. Solar panels are also proposed to the south of the Conservation Area within site 7F and although there is no specific reference to this in the submitted impact assessment, mitigation in the form of planting will also result in a harmful impact by severing the visual relationship between the Conservation Area and the surrounding open land in views out to the south. It is therefore concluded that the proposed development of sites 7D and 7F will have a harmful impact on the setting of Saxlingham Green Conservation Area which is considered to be less than substantial at the lower end of the scale.

6.55 **Sites 7I – 7L** proposes several areas of solar PV arrays on a number of parcels of land. **Oaks Farmhouse** is a high status, Grade II* listed building originating from the 16th century located in an isolated rural position to the east of site 7L, surrounded by open land which forms its setting and has historically remained undeveloped. Solar panels are proposed in relatively close proximity on existing open land on the west side of Woodton Road which is bounded by a low hedgerow. The submitted impact assessment acknowledges that sub-site 7L does contribute to the significance of Oaks Farmhouse and that there is intervisibility between the site and the listed building, but concludes at Paragraph 11.17 that the scheme will result in no harm to this heritage asset, noting that although there will be views of the solar PV arrays, proposed planting with screen them from the farmhouse once matured after approximately 15 years. However, although surrounded by some mature trees and vegetation, there are views out from the building across the surrounding open land to the south and to the west, along with views of the building towards the north and the east, with the degree of visibility increasing during the winter months (see photos 134-139). Taking account of the scale and height of the solar panels and their proximity to the west of the

farmhouse, they will be highly visible in views from and towards the building, introducing alien and incongruous, industrial features within its setting, standing above the existing hedgerow which forms the site boundary. Furthermore, it is noted that proposed augmentation of existing boundary planting will not effectively screen the panels until maturity after around 15 years. However, it is also considered that the proposed mitigation measures, will in themselves have a harmful impact by severing the visual relationship between the farmhouse and the surrounding open land. Taking account of the high status of the building and its distinctly rural setting which has remained undeveloped for centuries, it is concluded that the proposed development of site 7L will have a harmful impact of the significance of Oaks Farmhouse. This is considered to be less than substantial, but at a moderate level.

6.56 **Site 8** proposes several areas of solar PV arrays on a number of parcels of land. **Upgate Green Farmhouse** and the **Outhouse immediately to north** form an important group and are located in a relatively isolated position to the north of site 4B. They are surrounded by open and undeveloped farmland which has important historic connections with these buildings and this rural and gently undulating landscape setting, positively contributes to their significance. There are open views of this open land looking south from the buildings and looking north across the open land from the adjacent Brooke Road where the buildings are visible (see photos 144-147). The submitted impact assessment acknowledges that there will be some changes to their setting arising from the scheme but concludes at Paragraphs 12.22 and 12.23 that there will be no harm to their significance. Although the adjoining land immediately to the south of the buildings will remain open, the proposed solar panels are to be located on rising ground which will be visible on the skyline in views from the buildings. Taking into account the height of the proposed panels, the existing hedgerow will not provide sufficient screening and the enhanced planting proposed will not completely screen the panels for several years. The panels will introduce incongruous and industrial features into this attractive, open and undeveloped rural landscape setting and visibility both from and including these buildings, will result in a degree of harm to their significance. This is considered to be less than substantial at the lower end of the scale.

6.57 **Site 9** proposes several areas of solar PV arrays on a number of parcels of land.

6.58 **Waterfield Cottage** occupies a secluded position surrounded by hedges and mature trees, set back from the road, with only glimpses of the building when passing the entrance driveway. It is therefore agreed that the proposed development will not have an adverse impact on its significance.

6.59 **Oldhouse Farmhouse** and **Barn** form a group which are appreciated in views towards the west both from the adjoining road and from more distant views (see photos 150-153) . They are surrounded by open and undeveloped farmland which forms their setting, particularly to the east and to the south, with views across these areas both

from and towards the buildings (see photos 154-155). Solar PV arrays are proposed on site 9 to the east of the farmhouse and barn and paragraph 13.41 of the submitted impact assessment concludes that due to intervening vegetation screening and distance, there will be no intervisibility and the scheme will result in no harm to the significance of Oldhouse Farmhouse or the barn at Oldhouse Farmhouse. However, although the area closest to the buildings is to remain undeveloped, there are views both from and towards the site with the degree of intervisibility between the two increasing in the winter months. In views towards the site the proposed panels will be visible on the horizon and will introduce incongruous, industrial features within their open and undeveloped setting. It is therefore concluded that this will result in a harmful impact on their significance, which is considered to be less than substantial at the lower end of the scale.

6.60 **Littlebeck Farmhouse** is surrounded by open areas of farmland and although the main later façade faces east, there are views to and from the open land to the west where the earlier 17th century wing to the rear is visible, with greater visibility during the winter (see photos 158 & 159). Solar PV arrays are proposed on site 9 to the north-west of the farmhouse and paragraph 13.42 of the submitted impact assessment concludes that there will be no harm to the significance of the listed building as a result of the proposals. However, there is intervisibility between the proposed site for the solar panels and the farmhouse and in particular, views towards the east along Littlebeck Lane, where the development will be seen in the same view as the farmhouse, especially during the winter months. There is currently a distinctive open character to the existing farmland on either side of the lane, seen in these views towards the farmhouse, which forms its wider setting to the west. Solar panels are proposed immediately on the north side of Littlebeck Lane and taking account of their height and movement, this will introduce alien and industrial features into this open and undeveloped rural landscape. Any mitigation measures in the form of tree planting will take several years to provide any effective screening of the solar panels particularly given their proximity to the edge of the lane and furthermore, will create a strong sense of enclosure along the lane, resulting in the loss of the open character of the setting of the farmhouse from the west. It is therefore concluded that the development of site 9 will result in harm to the significance of Littlebeck Farmhouse which is considered to be less than substantial at the lower end of the scale.

6.61 **Brooke and Kirstead Conservation Area** lies to the north and east of site 9 with the High Green Character Area being closest. The existing open agricultural land to the south forms the setting of the Conservation Area. There are views to the north across this open land from Littlebeck Lane and from the footpath immediately to the west of the proposed solar panels within site 9, towards the Conservation Area, where buildings within the area are visible on the horizon interspersed amongst trees (see photos 160 & 161). Paragraph 13.39 of the submitted impact assessment acknowledges that there may be limited views of solar PV arrays within site 9 from the

cricket club, but concludes that there will be no harm to the setting of the Conservation Area and that the scheme will not result in negative impacts to its significance. However, considering the open setting of the Conservation Area to the south, views towards the north from the footpath and lane will be blocked by the addition of the solar panels creating an industrial landscape setting to the area. It is therefore concluded that the proposed development of site 9 will have a harmful impact on the setting of Brooke and Kirstead Conservation Area which is considered to be less than substantial at the lower end of the scale.

6.62 **Site 10** proposes several areas of solar PV arrays on a number of parcels of land, along with a 132kV substation within site 10C

6.63 There are glimpses of the **Old Rectory** through surrounding mature trees towards the east from Norwich Road, but there is very limited visibility of the building in views to the west from the site of the proposed solar panels, being largely obscured by surrounding mature trees. It is therefore agreed that the proposed development will not have an adverse impact on its significance.

6.64 **Beulah House** and **Beulah Barn** are set back from the main road with open farmland immediately to the north, to the east and to the south. This open area, forms their setting, with wide open views both from and towards the buildings (see photos 171 & 172) across this area. Further to the east, rising and undulating open farmland forms the backdrop in views from both properties (see photos 168 & 173). Solar PV arrays are proposed on this rising ground within sites 10A, B and C, along with a 132kV project substation. Paragraph 14.12 of the submitted impact assessment states *'…..the setting* (of Beulah House) *is largely rural with some restricted views over the fields to the rear of the house towards site 10. Even within the winter months, it is unlikely there would be any significant views of site 10 from the house'.* However, following a site visit, it is clear that due to the rising ground which forms the backdrop in views to the east, and noting the height and movement of the proposed panels, they will be clearly seen in a number of views, with the extent of visibility considerably increasing in the winter months. This is clearly illustrated in plate 57 'View from Beulah House towards sub-sites 10A and 10D facing east' within the submitted report. The assessment concludes that due to the proposed landscaping initiatives in the form of woodland planting and enhanced hedgerows, visibility will be removed or drastically reduced and no part of the scheme within site 10 will be visually prominent, the change in the settings of Beulah House and Beulah Barn will be negligible and therefore there will be no harm to their significance. Taking into consideration the site topography and the extent of visibility of the rising land along the horizon in views to the east, it is questionable whether the proposed planting will provide an effective degree of screening of the solar panels, which will in any case, take a considerable number of years to mature. In addition, a project substation is proposed within site 10C, close to the west boundary, and therefore likely to be visible in views to the east, which is neither referred to, nor any assessment made of its visual impact. It is therefore

concluded that there will be some adverse impact on the significance of Beulah House and Beulah Barn which is considered to be less than substantial at the lower end of the scale.

6.65 **Seething Conservation Area** lies to the north of site 10E and was identified as potentially affected but an impact assessment is not included in the submitted heritage statement. There are no large scale or suburban type extensions to the village which is largely included in the Conservation Area and retains its linear characteristics with surrounding relatively flat agricultural land forming its setting. This includes open and undeveloped land to the south which is experienced on approach to the Conservation Area along Upgate Road. Site 10E includes solar PV arrays which given their size and movement will be visible both when approaching the Conservation Area from the south and in view towards the south from within the area. This will introduce alien and industrial features within the open and undeveloped rural setting of the Conservation Area. It is therefore concluded that this will have an adverse impact on the setting of Seething Conservation Area which is considered to be less than substantial at the lower end of the scale.

6.66 The following table sets out a summary of all those designated heritage assets potentially affected by the proposed built development at East Pye Solar Farm on a site by site basis, along with the outcome of the heritage impact assessment submitted by the applicant and that of the heritage impact assessment carried out on behalf of BEPS as set out in section 6.0 of this report. Highlighted columns indicate those heritage assets where it is considered that there will be a greater degree of harm to their significance, than that identified in the applicant's assessment.

Heritage Asset	**Impact assessment in statement submitted by applicant**	**Impact assessment undertaken on behalf of BEPS**
Sites 1 & 2 and BESS		
Broadgate Way	No harm	No harm
Moulton Farmhouse	Low level of harm	Moderate level of harm
Laurels Farmhouse	No harm	Low level of harm
Barn to east of Laurels Farmhouse	No harm	Low level of harm
Hill House	No harm	Moderate level of harm
French's Farmhouse	No harm	No harm

Barn Cottages	Low level of harm	Moderate level of harm
Site 3		
Rose Cottage	No harm	No harm
Three Feathers	No harm	No harm
Barn and Stable Range	No harm	No harm
Townhouse Farmhouse	No harm	Low level of harm
Site 4		
Church of St Michael	No harm	Moderate level of harm
The Old Rectory	No harm	Moderate level of harm
Barn to the north	No harm	Moderate level of harm
Cottage occupied by [redacted] (Thatched Cottage)	No harm	Low level of harm
Church Farmhouse	No harm	No harm
The Cedars	No harm	Low level of harm
Pair of Houses [redacted]	No harm	Low level of harm
Cottage occupied [redacted] (Well Meadow Cottage)	No harm	No harm
The Hollies	No harm	No harm
Site 5		
Church Farmhouse	No harm	Low level of harm
Barn to the north-east	No harm	Low level of harm
Church of St Catherine	No harm	Moderate to high level of harm
Fritton Conservation Area	No harm	Low level of harm
Site 6		

	No harm to surrounding heritage assets	No harm to surrounding heritage assets
Sites 7A – 7C		
Countryman Public House	No harm	No harm
Hill Farmhouse	No harm	Low level of harm
Tramp's Hall	No harm	No harm
Barn immediately east	No harm	No harm
Former Quaker Meeting House	No harm	No harm
Wood Farmhouse	No harm	Low level of harm
Grove Farmhouse	No harm	Low level of harm
Sites 7D – 7H		
Manor Cottage	No harm	Low level of harm
Manor Farmhouse	No harm	Low level of harm
Manor Farmhouse Barn	No harm	Low level of harm
Hill Cottages	No harm	Low level of harm
Hill House	No harm	Low level of harm
Holly Cottage	Scoped out of further assessment as not considered to be impacted	Low level of harm
Saxlingham Green Conservation Area	No harm	Low level of harm
Sites 7I – 7L		
Oaks Farmhouse	No harm	Moderate level of harm
Site 8		
Upgate Green Farmhouse	No harm	Low level of harm

Outhouse immediately to north	No harm	Low level of harm
Site 9		
Waterfield Cottage	No Harm	No harm
Oldhouse Farmhouse	No harm	Low level of harm
Oldhouse Farmhouse Barn	No harm	Low level of harm
Littlebeck Farmhouse	No harm	Low level of harm
Brooke and Kirstead Conservation Area	No harm	Low level of harm
Site 10		
Old Rectory	No harm	No harm
Beulah House	No harm	Low level of harm
Beulah Barn	No harm	Low level of harm
Seething Conservation Area	Identified as potentially affected but no impact assessment made	Low level of harm

6.67 In addition to the proposed works involving built development of solar panels, the BESS, National Grid and Project Substations etc., the impact of which is considered above, there are a number of road widening and abnormal load routes proposed where there is also potential to impact on heritage assets. These include the proposed widening of the west end of Fairstead Lane, Tasburgh from the junction with the A140 Ipswich Road and the route through Saxlingham Nethergate along The Street and Church Hill.

6.68 The proposed works at Fairstead Lane include alterations to and widening of the junction with the A140, widening of the lane and hedgerow removal. Hill Farmhouse, a Grade II listed, 17th century timber framed and plastered building lies immediately to the north of Fairstead Lane at the junction with Ipswich Road. A further two, Grade II listed buildings, lie immediately to the south of Fairstead Lane; Tramp's Hall, a 17th century timber framed and roughcast house and the Barn immediately to the east of Tramp's Hall, which is also timber framed, dating from the 17th century. Despite the proximity of these heritage assets to the proposed works, the submitted Heritage

Statement neither makes reference to the proposals, nor assesses the impact of the works on their setting and overall significance.

6.69 Fairstead Lane is a narrow, single track, ancient sunken lane, lined by hedgerows and is distinctly rural in character. It forms part of the rural setting of Hill Farmhouse which adjoins the north side of the lane with a hedgerow lining its rear boundary along the lane. The lane also forms the setting of Tramp's Hall and the adjacent barn, with curtilage outbuildings abutting the verge on the south side. The proposed road widening works and alterations to the junction, together with the loss of hedgerows and green verges will introduce an incongruous urban character within the setting of these buildings. Furthermore, taking account of the proximity of buildings to the lane, there are concerns about the impact of continuous large vehicle movements on these timber framed structures. It is therefore concluded that the works proposed on Fairstead Lane will have a harmful impact on the significance of Hill Farmhouse, Tramp's Hall and the Barn immediately to the east, which is considered to be less than substantial at the lower end of the scale.

178 & 179: Hill Farmhouse to north-east at the junction of Ipswich Road & Fairstead Lane and view west along Fairstead Lane with hedgerow and verge to the rear

180 & 181: Fairstead Lane looking east at the entrance to Tramp's Hall with the barn on the right and outbuildings abutting the verge and looking west along Fairstead Lane lined by hedgerows

6.70 With regard to the proposed works within Saxlingham Nethergate, paragraph 15.7 of the submitted Heritage Statement notes the following: *'An abnormal load route has been identified as potentially being required within the Saxlingham Nethergate Conservation Area, along the roadside of a total of 13 Grade II listed buildings and 10 non-designated heritage assets. Of these, there are three buildings situated close to the bend in the roadside on this route: the Grade II listed the Old School (NHLE 1050668), and two non-designated heritage assets: Orchard View and Orchard View Barn. This route will likely be used for a small number of movements (less than ten) required to deliver abnormal loads to construct the substation within site 7. The swept path analysis of the route has identified this section of the road within the Conservation Area as most likely requiring temporary roadworks and the suspension of all on street parking areas along the road. Where the load may potentially oversail, it is further possible that tree canopies within the Conservation Area may need to be trimmed back and the roadside railings or bollards may need to be temporarily removed. The latter are modern and will be reinstated immediately following. There will be no changes made to the Conservation Area or other designated heritage assets. There will also be a construction traffic management plan in place to ensure that the movements are closely monitored so as to reduce any risk to surrounding structures, It is therefore, considered that this will result in no harm to the identified heritage assets or the character and appearance of the Conservation Area'.*

6.71 The works proposed are along The Street and Church Hill which lie within the Saxlingham Nethergate Conservation Area, originally designated in 1973. There are numerous listed buildings and buildings of local interest (non-designated heritage assets) either abutting or in close proximity to the road, including several timber framed and clay lump structures. The Conservation Area Character Appraisal and Management Guidelines adopted by South Norfolk Council in December 2018 describe Saxlingham Nethergate as one of the principal historic villages in the District, which developed as a linear settlement along the line of a stream. It also notes that mature hedgerows and low brick and flint walls at front boundaries are key features which positively contribute to the character of the area. The Grade II listed War Memorial provides an attractive focal point set within the green triangular space where The Street curves round towards Church Hill. At the top of the hill is an important group of high-status buildings, each of which is Grade II* listed, including The Old Rectory, the Church of St Mary and The Old Hall. The Old Rectory, dating from 1784, was designed by Sir John Soane. It sits within its own secluded landscaped setting, with the tall mature hedgerow, trees and boundary wall enclosing its surrounding gardens, forming an important feature abutting the verge on the north side of Church Hill.

6.72 The precise nature of the works required in order to create sufficient space to accommodate the abnormal load route for transportation of equipment to construct the substation within site 7, is unclear. However, it is understood that it is intended to compulsory purchase land from the War Memorial and from the Church Hill frontage

of The Old Rectory to enable the removal of the roadside hedge and the listed boundary wall. Any proposed works involving widening of the road, removal of green verges and the loss of hedgerows would impact on the setting of the War Memorial and The Old Rectory. Furthermore, taking account of the proximity of historic buildings to the road, there are concerns about the impact of continuous large vehicle movements on these timber framed and clay lump structures. It is therefore concluded that the works proposed in Saxlingham Nethergate will have a harmful impact on the significance of the War Memorial and the Old Rectory, which is considered to be less than substantial at the lower end of the scale. There will also be an adverse impact on the character and appearance of the Conservation Area, which would neither be preserved nor enhanced. Any works involving removal or demolition of historic fabric, such as the original brick and flint boundary wall to The Old Rectory, would result in harm at the high end of the scale.

182-185: View to the north along The Street and views around the War Memorial green showing the relationship with surrounding buildings and proximity to The Street

186-189: Views to the east and west along Church Hill showing buildings abutting the verge and the mature hedgerow, trees and wall forming the boundary to The Old Rectory on the north side of Church Hill.

7.0 Conclusions

7.1 The Heritage Statement submitted with the application notes that, following an initial assessment using a combination of desk-based research, viewshed analysis and site visits, a total of 51 designated heritage assets were identified for further assessment, being potentially affected by the proposed development. This includes one Scheduled Monument, two Grade I listed buildings, two Grade II* listed buildings, 42 Grade II listed buildings and four Conservation Areas.

7.2 It is agreed that this list includes those heritage assets most likely to be impacted, although a small number of other heritage assets have been added to the list for further consideration. Site visits have been made to all of these listed buildings and Conservation Areas and an assessment undertaken of their significance and setting and the impact of the proposed development, as set out in Sections 4.0 and 6.0 of this report.

7.3 It is important to have a thorough understanding, prior to undertaking any assessment, of the fundamental and intrinsic relationship between the locally distinctive, traditional historic buildings within the area proposed for development and their surrounding landscape formed by the South Norfolk Claylands. Buildings are firmly rooted in their location, having been constructed from locally available materials and positively contribute to the character of the landscape, whilst the landscape itself forms an important part of their setting. This landscape has a distinctive, rural character creating a strong sense of place, with its predominantly open, green and agricultural qualities. The Historic England Farmstead and Landscape Statement for the area notes that it is an intensively farmed landscape, predominantly under arable cultivation, with 98% of the Character Area being open landscape, 90% of that land being under arable cultivation and less than 2% being urban or classified as non-agricultural and 3% being wooded. The area contains several important examples of pre-1750 farmstead buildings, along with historic churches and other vernacular buildings. This landscape, which forms the setting of many historic buildings is therefore highly sensitive to change, with relatively small changes having the potential to have a harmful impact on the relationship between landscape and buildings, which has in many cases remained open and undeveloped for several centuries.

7.4 Paragraph 2.10 of the applicant's Heritage Statement refers to the National Policy Statement for Renewable Energy Infrastructure (EN-3), 2025, which sets out government policy on developments for Solar Photovoltaic Generation, with paragraphs 2.10.99-111 referring to specific conditions in regard to cultural heritage. In particular, it is noted that: *'The impacts of solar PV developments on the historic environment will require expert assessment in most cases and may have effect both above and below ground. Above ground impacts may include the effects on the setting of Listed Buildings and other designated heritage assets as well as on the* ***Historic Landscape Character****'.* The historic agricultural landscape which surrounds the proposed development is not merely background to the listed buildings which sit within it and the key characteristics noted in the above paragraph and set out in more detail within Section 2.0 of this report, are entirely relevant considerations in the assessment of the overall heritage impact. There are concerns at the wider cumulative impact of the proposals on the historic landscape character. Whilst the assessment identifies low to moderate harm to the setting of several individual buildings across the landscape, cumulatively, when experienced moving through the landscape, there will be greater negative impact than on any one building individually. The proposed development will change the character of the whole historic area, with negative consequences even for listed buildings not directly affected by the scheme.

7.5 The Overarching National Policy Statement for Energy (EN-1) requires cumulative effects to be considered. The relevant representation from Historic England notes that changes to setting are likely in some cases to equate to policy harm, that residual effects are likely to remain and raises potential concerns about the cumulative effects

with Tasway Energy Park and associated BESS projects, which requires further consideration. Although the assessment of the cumulative impacts does not lie within the scope of this assessment undertaken on behalf of BEPS, it should be noted that the points raised by Historic England are supported and consideration should therefore be given as to whether successive infrastructure changes will cumulatively erode the rural historic setting of heritage assets as part of the overall heritage impact assessment.

7.6 Table 10-3 'Sensitivity Criteria of Identified Receptor' within the Environmental Statement Volume 1 : Chapter 10 -Cultural Heritage, refers to Grade II listed buildings as being of medium (regional) sensitivity. The majority of listed buildings potentially affected by the proposed development are Grade II listed, indeed 92% of listed buildings nationally are Grade II listed. All buildings on the statutory list of buildings of special architectural or historic interest are recognised as being of national importance. Grade II buildings are buildings of special interest, warranting every effort to preserve them. The Environmental Statement is therefore incorrect in describing Grade II listed buildings as being of regional value only. Furthermore, the degree of sensitivity to changes in setting will very much depend on the significance of the asset itself and its relationship with the proposed development, with each case having to be assessed on its own merits. Grade II listed buildings are nationally designated heritage assets, not a regional designation and labelling such buildings as 'regional' as noted in the applicant's statement, has the potential to mislead the assessment and result in reduced policy weight being given to such heritage assets.

7.7 The applicant's Heritage Statement notes that the assessments of setting and impact have been undertaken in accordance with the Historic England Good Practice Advice 3 *'The Setting of Heritage Assets'.* However, the assessments focus heavily on views, with several other relevant factors which contribute to setting not being considered such as openness and enclosure, site topography, associative relationships with other heritage assets, history and degree of change over time, tranquillity, remoteness etc. In some cases, there is insufficient assessment of the extent of intervisibility between the proposed development and surrounding heritage assets and in particular seasonal changes, with increased visibility and prominence of built development during the winter months. This includes, amongst others, the Church of St Catherine, Fritton and its historic relationship with surrounding, undeveloped land; distinct sense of peace, tranquillity and isolation; and considerable increase in intervisibility between the church and the site proposed for development in the winter, along with the Church of St Michael, The Old Rectory and the Barn to the north at Stratton St Michael, which form an important group and have historic connections and intervisibility with surrounding open and undeveloped farmland.

7.8 The Heritage Statement includes a number of 'Heritage Viewpoints'. However, the methodology and criteria for the selection of these viewpoints is unclear. Those included appear to have been chosen to support the conclusion that there will be no

adverse impact arising from the proposed development. There are no viewpoints to illustrate areas where harm has been identified and additional viewpoints would be beneficial to fully assess the overall impact, including modelling of the following:

- Winter view from the churchyard of the Church of St Catherine, Fritton towards Site 5 and the substation.
- Panoramic view of Site 4 from the new footbridge, Stratton St Michael.
- The Cedars, Long Stratton to west and east.
- View to the west towards Site 2A from Hill House, Pulham Market.
- View from Oaks Farmhouse, Woodton towards Site 7L.
- Barn Cottages, Tivetshall St Margaret along Station Road.
- Saxlingham Green approach from Broaden Lane.
- Beulah House and Barn, Woodton towards Site 10 and substation.

7.9 The scale and height of the proposed solar panels at 4.5 metres, together with their movement will increase their prominence and visibility within the setting of heritage assets. It is of particular concern that they will introduce incongruous and industrial features within the distinctly rural, open and undeveloped character of the surrounding landscape.

7.10 There is potential for considerable adverse impacts on the setting of heritage assets arising from the proposed BESS, National Grid Substation and Project Substations through the introduction of structures with an industrial character. Although the applicant's assessment is based on maximum parameters, the exact BESS, substation, gantry, acoustic barrier and enclosure designs remain flexible. In the absence of full details of these substantial elements of the scheme including scale and height; details of proposed built structures, plant and equipment; noise levels and noise barrier screening; boundary treatments and enclosures; materials etc., it is not possible to fully assess their impact on the significance of heritage assets and the effectiveness of any mitigation measures. This is particularly relevant to impacts at Moulton Farmhouse, Barn Cottages, Stratton St Michael, the Church of St Catherine, Fritton and Beulah House and Barn. The impacts of noise from these elements of the project have not been fully considered and in particular the effect on the tranquillity of the churchyard at the Church of St Catherine, along with impacts on Barn Cottages, Stratton St Micheal and rural Conservation Areas.

7.11 The mitigation measures proposed generally include additional landscaping in the form of tree and some woodland planting along with some hedgerow reinforcement. However, a number of these measures will in themselves have a harmful impact on the setting of several heritage assets by creating a sense of enclosure which previously never existed, blocking important views or severing the visual and historic relationships between heritage assets and their open and undeveloped settings, which positively contribute to their significance. Furthermore, it will take several years for planting to mature before providing effective screening of

solar panels etc., (acknowledged to be up to 30 years in some instances) which would in any event be reduced during the winter months. With panels having a height of 4.5 metres, existing hedgerows or indeed hedgerow reinforcement will not provide sufficient screening. Guidance provided by Historic England in paragraph 40 of *'The Setting of Heritage Assets'* states that *'As screening can only mitigate negative impacts, rather than removing impacts or providing enhancement, it ought never to be regarded as a substitute for well-designed developments within the setting of heritage assets'.* Taking account of the extent of mitigation measures required, in the form of planting to reduce harmful impacts, it cannot therefore be said that the proposed development is well-designed. There are a number of particularly sensitive sites where it is considered that the proper heritage response should be avoidance or deletion of development, rather than screening through the provision of planting which cannot preserve significance, in particular sites 4B, 5B and 7L.

7.12 There are a number of areas where it is acknowledged that some recent development has resulted in a degree of harm to the setting of heritage assets, notably the impact of the bypass at Stratton St Micheal. However, it should be emphasised that existing harm is not a justification for causing further harm. A degraded setting may still make a positive contribution to significance and further industrialisation can compound rather than neutralise the effect. This is the case at the group of high status listed buildings in Stratton St Micheal where the new bypass has had some adverse impact, but the construction of the new footbridge has opened up panoramic views of their open and rural setting to the north, which still positively contributes to their significance. Furthermore, the applicant's identification of the existing industrial buildings and structures in the vicinity of site 1, is not a valid justification for the addition of further incongruous industrial structures within the rural landscape which will adversely impact on the significance of surrounding heritage assets.

7.13 It is agreed that there will be no direct impacts and no substantial harm to the significance of any heritage assets arising from the proposed built development works. However, the proposals will affect the setting of several heritage assets, resulting in less than substantial harm to their significance, although it is considered that these adverse impacts will affect a greater number than those identified in the applicant's Heritage Statement.

7.14 The concluding paragraph 16.9 of the applicant's Heritage Statement notes: *'In summary, there are two designated heritage assets where the impact of the scheme will be minor/negligible. The level of harm caused by this impact is considered to be less than substantial at the lower end of the scale. There will be no harm to any other designated or non-designated heritage asset arising from the scheme'.* The two designated heritage assets where a harmful impact has been identified are Moulton Farmhouse, Great Moulton and Barn Cottages, Tivetshall St Margaret, although it has also been noted that in the case of Barn Cottages, this will be reduced to no harm,

once the landscaping screening of the project substation within the BESS sub-site has matured (expected to be approximately 30 years).

7.15 The table at paragraph 6.66 of this report summarises the outcome of the impact assessment undertaken on behalf of BEPS, arising from the proposed built development of solar PV arrays, the BESS, National Grid and Project Substations, as set out and described in detail in Section 6.0. This identifies some degree of harm, which will be less than substantial, to the significance of 36 designated heritage assets, compared with only 2 in the applicant's Heritage Statement. This includes a low level of harm to the significance of 24 listed buildings and a low level of harm to the setting of 4 Conservation Areas. In addition, the degree of harm to the significance of a further 8 listed buildings, is considered to be at a higher level than that identified in the applicant's statement. Of particular concern are the impacts on the Grade I listed Church of St Catherine, Fritton; the group at Stratton St Michael comprising the Grade I listed Church of St Michael, Grade II* listed Old Rectory and Grade II listed Barn to the north; Grade II* listed Oaks Farmhouse, Woodton and Grade II listed Moulton Farmhouse, Great Moulton; Hill House, Pulham Market and Barn Cottages, Tivetshall St Margaret.

7.16 In addition there are adverse impacts arising from the proposed road widening works and abnormal load routes in Fairstead Lane, Tasburgh and through the village of Saxlingham Nethergate, as set out in paragraphs 6.67 to 6.72. This identifies less than substantial harm at the lower end of the scale to the significance of 3 additional Grade II listed buildings and the Grade II* listed Old Rectory in Saxlingham Nethergate, as well as harm to the character and appearance of the Conservation which will neither be preserved nor enhanced. Any works involving the removal or demolition of the boundary wall to The Old Rectory will have a direct impact on historic fabric resulting in harm at the higher end of the scale. Fairstead Lane is an ancient sunken lane bounded by hedgerows and is distinctly rural in character, Saxlingham Nethergate is one of the principal historic villages within South Norfolk and was designated a Conservation Area in 1973, which includes numerous listed buildings and buildings of local interest. The routes proposed are therefore considered to be wholly inappropriate for the transport of large pieces of equipment and abnormal loads.

7.17 It is therefore concluded that there are considerable adverse impacts on the significance of several heritage assets including high status churches and historic farmsteads, which are greater than those identified in the applicant's statement. Sections 66 and 72 of the Planning (Listed Buildings and Conservation Areas) Act 1990 requires decision makers to give special regard to the desirability of preserving listed buildings and their settings and preserving or enhancing the character or appearance of Conservation Areas. This statutory presumption in favour of preservation must be given considerable importance and weight.

7.18 Section 5.9 of the Overarching National Policy Statement for Energy (EN-1) sets out policy details in relation to the historic environment. Paragraph 5.9.28 requires great weight to be given to the conservation of a designated heritage asset and the more important the asset, the greater that weight should be, irrespective of the level of harm. Particular note should be taken of the adverse impacts identified on the following high status buildings:

- Grade I Church of St Catherine, Fritton
- Grade I Church of St Michael, Stratton St Michael
- Grade II* Old Rectory, Stratton St Michael
- Grade II* Oaks Farmhouse, Woodton
- Grade II* Old Rectory, Saxlingham Nethergate

7.19 Where proposed development will lead to less than substantial harm to the significance of a designated heritage asset, Paragraph 5.9.33 requires the harm to be weighed against the public benefits of the proposal. Paragraph 5.9.37 requires the Secretary of State to give great weight to any negative effects, when weighing them against the wider benefits of the application. The greater the negative impact on the significance of the designated heritage asset, the greater the benefits that will be needed to justify approval.

7.20 Taking account of the negative impacts identified on the significance of 2 Grade I listed buildings and 3 Grade II* listed buildings, together with the cumulative negative impacts identified on the significance of 36 other designated heritage assets, in comparison with the applicant's assessment, this must be given considerable weight in the overall planning balance.

Appendix A : References

- Overarching National Policy Statement for Energy (EN-1), Department for Energy Security & Net Zero, 2025
- National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, 2025
- National Planning Policy Framework, Ministry of Housing, Communities & Local Government revised August 2026
- National Planning Practice Guidance : Historic Environment, Department for Levelling Up, Housing & Communities and Ministry of Housing, Communities & Local Government, www.gov.uk 23 July 2019
- Planning (Listed Buildings & Conservation Areas) Act 1990

- Historic Environment Good Practice Advice in Planning : GPA2 'Managing Significance in Decision-Taking in the Historic Environment', Historic England, July 2015
- Historic Environment Good Practice Advice in Planning : GPA3 'The Setting of Heritage Assets', Historic England, Dec 2017
- Making Changes to Heritage Assets; Historic England Advice Note 2, February 2016
- Statements of Heritage Significance : Analysing Significance in Heritage Assets; Historic England Advice Note 12, October 2019
- Conservation Principles, Policies and Guidance; Historic England, April 2008
- Greater Norwich Local Plan, March 2024
- Saxlingham Green Conservation Area Character Appraisal and Management Guidelines, South Norfolk Council, December 2018
- Fritton Conservation Area Character Appraisal and Management Guidelines, South Norfolk Council, December 2019
- Brooke and Kirstead Conservation Area Character Appraisal and Management Guidelines, South Norfolk Council, May 2025
- Seething Conservation Area Character Appraisal and Management Guidelines, South Norfolk Council, December 2019
- Saxlingham Nethergate Conservation Area Character Appraisal and Management Guidelines, South Norfolk Council, December 2018
- Norfolk Historic Environment Record
- National Heritage List for England www.historicengland.org.uk/listing/the-list
- Historical Map Archive : National Library of Scotland
- Farmstead and Landscape Statement ‘South Norfolk and High Suffolk Claylands’ National Character Area 83; Historic England 2020
- 6.1.10 Environmental Statement Volume 1: Chapter 10 - Cultural Heritage (Revision 1)
- 6.3.10.1 Environmental Statement Volume 3: Appendix 10.1 - Heritage Statement (Revision 1) - Parts 1, 2, 3 & 4

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Briefing Note

The Secretary of State for Energy Security and Net Zero (ESNZ) appears to have influenced the National Energy System Operator (NESO), which is supposed to be an independent adviser to the Department for Energy Security and Net Zero (DESNZ), to change their advice and targets in direct response to solar industry lobbying.

The Secretary of State for ESNZ is solely responsible for granting development consent to the very Nationally Significant Infrastructure Projects (NSIP) solar projects about which he is being directly lobbied.

This sequence of developer representations followed by ministerial instruction and NESO revisions raises a real possibility of apparent bias in the Secretary of State for ESNZ's quasi-judicial role. This may warrant scrutiny under the Ministerial Code for impartiality, potentially requiring recusal to uphold public confidence. Decision-making under such influence would be tainted by apparent bias (Porter v Magill [2001] UKHL 67).

All assessments regarding procedural fairness, apparent bias and statutory independence represent our interpretation of publicly available material and Freedom of Information (FOI) disclosures. They are expressed as matters of public interest and concern, not assertions of fact about any individual's or organisation's motives.

Background and Evidence.

Transmission Solar oversupply and 'Zombie' Projects

It was already apparent to DESNZ during the summer of 2024 that there were far more solar and battery projects in the Transmission connection pipeline than were necessary to meet even the UK's projected need for 2050. The National Energy System Operator (NESO) determined that many of these were speculative 'zombie' projects that were taking up space in the connection queue but were unlikely ever to be built. Because the transmission queue

worked on a 'first come first served' basis, this speculative over-supply was preventing projects that were actually ready to 'energise' from getting timely grid connections.

Solar projects connecting to the transmission network are typically the huge over 100MW ground-mounted schemes of several thousand acres that fall under the Nationally Significant Infrastructure Project (NSIP) planning regime. These projects by-pass local planning, are examined by the Planning Inspectorate and the final decision on whether they should be granted development consent is made by the Secretary of State for Energy Security and Net Zero.

Solar projects connecting to the distribution network are the smaller local schemes, typically on the roofs of businesses or homes, local car parks, warehouses or former industrial sites. This locally distributed energy benefits consumers and local businesses because it is directly generated by them, controlled by them and genuinely reduces their electricity costs. The electricity is used locally and does not need to be transported across the country via an upgraded grid. When there is an oversupply of energy, there are no constraint payments to flexible generators on the distribution network, unlike the utility scale generators connecting to the transmission network. This is one reason why many large solar developers are trying to secure transmission-level connections instead, and stringing lots of smaller solar projects together into large single NSIP applications to connect to the transmission rather than distribution network. NESO's recommendation in the Clean Power 2030 Action Plan was that 90% of solar should connect to the distribution network, and this was backed up by DESNZ's 'Rooftop Revolution' policy of promoting distribution projects that would genuinely lower consumers' electricity costs.

1. **Connections Reform**

   NESO proposed to solve this problem of oversupply and connection delays by a new 'connections reform methodology'. Rather than just allocating grid connections on a 'first-come-first-served' basis, NESO would now reassess all existing connection offers for transmission projects and reallocate them on a new basis of 'readiness' and 'alignment'. This new methodology was first advised by NESO 5 November 2024, published as part of the Clean Power Action Plan 2030 on 20 December 2024, and approved by Ofgem on 15 April 2025.

2. **Clean Power 2030 Action Plan Transmission Targets**

   In the Clean Power 2030 Action Plan published in December 2024, on the basis of independent advice from NESO, clear regional targets were given for the maximum capacities of different types of energy generation on the transmission network (see table on next page). For example, East Anglia only needed another 100MW of solar to

reach its required 2030 transmission target and another 900MW of transmission connected solar to meet its 2035 target.

Clean Power 2030 Action Plan: Connections reform annex

Transmission connected technologies

Table 2: Regional capacity breakdowns for transmission connected technologies required for 2030[20] and 2035[21]

Transmission network region	Solar (MW) 2030	Solar (MW) 2035	Onshore wind (MW)[22] 2030[23]	Onshore wind (MW) 2035	Batteries (MW)[24] 2030	Batteries (MW) 2035
N. Scotland	100	800	5,500	-	1,900	1,900
S. Scotland	600	800	8,800	-	3,900	3,900
N. England	500	1,400	-	-	800	800
N. Wales, the Mersey and the Humber	1,200	1,700	300	-	4,200	4,200
Midlands	4,000	5,200	-	-	1,300	1,300
Central England	2,100	3,300	-	-	500	500
E. Anglia	100	900	-	-	200	200
S. Wales and the Severn	1,100	1,300	1,300	-	900	900
S.W. England	300	300	-	-	400	400
S. England	200	200	-	-	100	100
South East England	600	1,100	-	-	1,700	1,700
GB total	**10,800**	**17,000**	**15,900**	**-**	**15,900**	**15,900**

Note: MW capacity figures have been rounded to the nearest 100 MW.

[20] The national total capacities (MW) per technology, are aligned with the DESNZ Clean Power Capacity ranges for 2030.
[21] The 2035 figures are informed by FES24 net-zero aligned scenarios.
[22] We have not presented onshore wind's breakdown by transmission network region for 2035. The capacity split between Scotland and England and Wales has been presented in Table 6.
[23] Some onshore wind regional capacities are blank for 2030 due to the lack of known pipeline transmission connected projects in these regions at the point of publishing.
[24] The 2 GW total uplift in estimated capacity between 2030 and 2035 for batteries has been allocated to distribution connected batteries only. There is, therefore, no change in the capacity breakdown for transmission connected batteries between 2030 and 2035.

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Solar developers needed to demonstrate that their transmission connected project was both ready (it had either land agreements in place or planning consent) and was aligned with the regional targets NESO had set out in the Clean Power 2030 Action Plan for either 2030 or 2035 connection.

Projects which could prove they were both 'ready' and 'aligned' would be offered a secure 'gate 2' connection offer by NESO, whereas those that were not ready or in excess of NESO's regional targets would be offered a 'gate 1' connection and would have the opportunity to reapply in future if their project became 'ready' or necessary to meet the regional target.

For example, in East Anglia, the transmission targets for solar set out by NESO were quite low (100MW for 2030 and 900MW for 2035). This is because the transmission network in East Anglia is primarily intended to transport electricity generated by the many off-shore wind turbines off the coast of Norfolk and Suffolk. There is therefore a limited need for transmission connected solar projects in this region as they would just cause unnecessary grid congestion and would need to be 'constrained off' at times of excess generation as the off-shore wind energy would be given priority on the network. This is the reason why the regional targets are important because they reflect local grid conditions.

3. NESO Analysis of the solar pipeline

In December 2024, NESO published analysis of the solar transmission queue both on a national level and for different regions in relation to the Clean Power 2030 and 2035 maximum permitted capacities (*NESO Connections Reform Data Impact Assessment, December 2024*). lar projects with consent or in planning to more than meet the national maximum transmission targets for both 2030 and 2035.

Figure 27. Transmission queue with project planning status

At national transmission level, there is no oversupply of projects with planning consents for solar or onshore wind, although there is a small oversupply of batteries compared with the 2035 permitted capacities.

Figure 27 shows that there is a high proportion of transmission-connected solar and battery projects that have submitted planning, which would significantly exceed the CP30 2030 and 2035 transmission-level permitted capacities if it all gained planning consent before 'go live'.

Stop Oversized Solar
Community groups opposing Nationally Significant Infrastructure Project (NSIP) solar proposals in Anglesey, Bedfordshire, Buckinghamshire, Cambridgeshire, Kent, Lincolnshire, Norfolk, Northamptonshire, Nottinghamshire, Suffolk, Wiltshire and Yorkshire: Block East Pye Solar • Claydons Solar Action Group • East Riding Against Solar Expansion • Fields of Glass • Grwp Cadw Tir Môn • Hands Off Our Marsh • Kingsway Solar Community Action • Mallard Pass Action Group • Say No to One Earth Solar Farm • Say No To Sunnica • 7000 Acres • Springwell Solar Action Group • Stop East Park Energy • Stop Greenhill Solar • Stop Lime Down • Stop Mylen Leah • Villages Against Solar Threat

Their analysis of the current distribution queue showed that there were adequate solar projects to meet 2030 maximum capacity and to almost meet the 2035 maximum capacity.

Figure 28. Distribution queue with project planning status (based off RFI responses)

For some regions, for example East Anglia, it became apparent that the current full queue for transmission connections was already vastly in excess of what was actually required by the Clean Power 2030 Action plan for either 2030 or 2035.

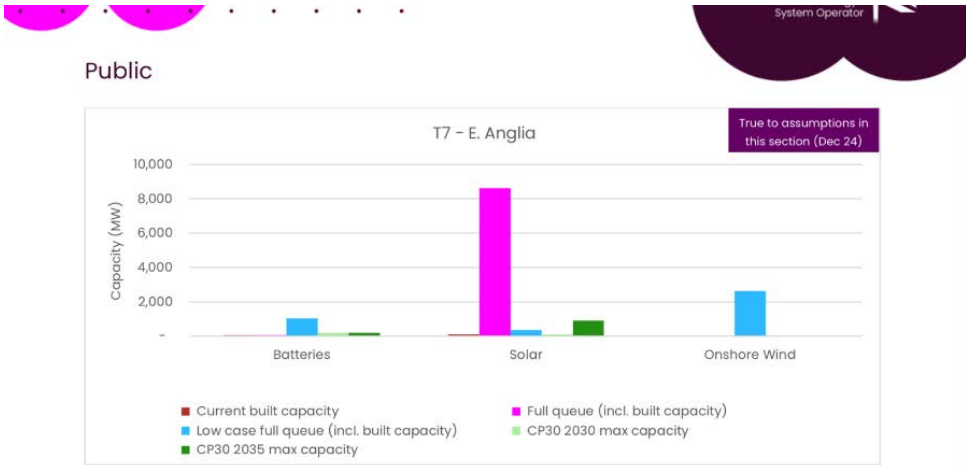


Figure 67. T7 – E. Anglia - Full transmission queue compared to CP30 2035 permitted capacities

Stop Oversized Solar
Community groups opposing Nationally Significant Infrastructure Project (NSIP) solar proposals in Anglesey, Bedfordshire, Buckinghamshire, Cambridgeshire, Kent, Lincolnshire, Norfolk, Northamptonshire, Nottinghamshire, Suffolk, Wiltshire and Yorkshire: Block East Pye Solar • Claydons Solar Action Group • East Riding Against Solar Expansion • Fields of Glass • Grwp Cadw Tir Môn • Hands Off Our Marsh • Kingsway Solar Community Action • Mallard Pass Action Group • Say No to One Earth Solar Farm • Say No To Sunnica • 7000 Acres • Springwell Solar Action Group • Stop East Park Energy • Stop Greenhill Solar • Stop Lime Down • Stop Mylen Leah • Villages Against Solar Threat

In their documents assessing the impact of the new Connections Reform Methodology, both NESO and Ofgem had anticipated this outcome and concluded that some solar projects hoping to connect to the transmission network would have to fall by the wayside due to this clear oversupply. They argued that this was part of the risk of putting forward a proposal for any type of project and should be anticipated by developers – they should assume that not every project would get a grid connection or development consent. In East Anglia their calculation was that 64% of solar projects would need to be removed from the queue (TMO4+ pg.188). The majority of these would be the vast utility scale transmission projects proposed by international solar developers.

4. **Lobbying by Solar Developers – private letter to Secretary of State for DESNZ**

By December 2024 and both the draft and publication of NESO's analysis, it was clear to solar developers that there was a vast oversupply of projects in the transmission queue which would not receive grid connections under the new 'gate 2' 'ready and aligned' methodology and they began to privately lobby DESNZ.

On 3 December 2024, representatives from Island Green Power, Enso Energy, Clearstone Energy and Innova wrote directly to Ed Miliband, the Secretary of State for ESNZ requesting an urgent meeting to discuss NESO's 'independent' advice to the government. This letter (attached) has been obtained through a Freedom of Information Request (FOI) EIR2025/09566 and an appeal to the Information Commissioner's Office (IC-401793-Y0Q9). DESNZ has also admitted through FOI (EIR2025/09566 IR2025/11361) that Island Green Power's 100% owner Australian bank Macquarie (who previously owned Thames Water), also lobbied DESNZ during this period about grid connections, sending letters on 28 November 2024, emails in December 2024 and January 2025, had a meeting on 13 January 2025, held a 'workshop' between Macquarie, DESNZ and NESO on 27 January 2025, and sent another letter to the Secretary of State for DESNZ on 15 May 2025. The Information Commissioner is currently assessing whether these communications should be released under FOI.

The solar developers write that certain aspects of NESO's 'Clean Power 2030 advice need to be reconsidered'. The first of these is NESO's advice that 90% of solar generation should connect to the distribution network. (As explained above these projects directly benefit individual consumers, local communities and local

businesses with genuinely cheap energy and do not require energy to be transported vast distances to end users, unlike transmission connected solar, or given payments to be constrained off). The government's 'Rooftop Revolution' campaign relies on connection to the distribution network and genuinely would give access for communities to cheap, renewable energy without industrialising hundreds of thousands of acres of prime UK farmland surrounding our ancient villages and cherished landscapes solely for the benefit of international developers as these vast transmission projects will do.

The solar developers wrote that NESO's advice on regional transmission targets would result in 'the majority of 'ready to connect' transmission solar projects being cancelled.' This is because they would be in excess of NESO's regional targets and would not meet the 'ready and aligned' criteria and therefore not be given gate 2 grid connections.

In the case of East Anglia, which we have been following, neither of Island Green Power/Macquarie's vast NSIP projects on productive farmland in Norfolk with a combined capacity of 1GW would receive gate 2 grid connections under NESO's new methodology because they were both in excess of either the Clean Power 2030 or 2035 targets for the region. As explained above, the transmission network in East Anglia is designed to carry energy from offshore wind, so there would be a high likelihood that any excess solar projects given connections to the transmission network would have to be regularly switched off in times of wind over-generation, resulting in consumers being hit with constraint payments.

The solar developers ask in their letter to the Secretary of State for ESNZ: 'We therefore urgently urge the government to reassess the allocation of solar across transmission and distribution, or remove the distinction between the two altogether.'

They claim that there are inadequate projects in the distribution queue to meet the 2030 targets and therefore the excess transmission projects are needed. However, we have already seen from NESO's analysis above (figure 28) that this is not the case. There are more than enough projects in the distribution queue for 2030 and almost enough to even meet the 2035 targets in a decade's time. Due to the increasing number of homes and businesses installing their own solar arrays, it is highly likely that any current room in the distribution capacity would be filled by 2035.

This proposal to over supply solar on the transmission network is not in the interests of consumers, food security, wildlife or the UK countryside and its communities – it is only in the interests of developers of vast ground-mounted solar schemes on farmland

who are backed by international banks and private equity firms who will control energy generation and energy prices to maintain their profits. The UK is already an outlier in Europe in allowing these vast schemes on farmland at all – other European countries such as Italy have already banned them, or like Germany and the Netherlands, they only approve schemes a fraction of the size of those proposed for UK farmland. In France such schemes are only permitted if they are genuinely 'agrivoltaics' and produce the same quantity and quality of crops as before the solar infrastructure was installed. These proposed NSIP projects in the UK do not involve any continued farming (token sheep to mow the grass annually is not genuine farming), and there is increasing evidence that productive farmland is significantly damaged by such solar infrastructure, potentially taking several generations after decommissioning, if ever, to recover (The impact of solar photovoltaic (PV) sites on agricultural soils and land quality Work Package Three SPEP2021-22/03). The harm caused by these excess transmission projects is not outweighed by any need for them.

The removal of the distinction between transmission and distribution proposed by the solar developers would mean that the combined regional targets would be much higher than the transmission-only targets, therefore allowing NESO to grant gate 2 grid connections to many more transmission connected solar projects than its independent, original targets required, or than NESO considered necessary for an effective regional energy mix.

The solar developers conclude their letter: 'We understand that the government's *Clean Power 2030 Action Plan* is due to be published imminently, and we are therefore acting with urgency to ensure that the proposals are viable and supportive of the government's ambition in this space.' Their aim is to influence DESNZ's *Clean Power 2030 Action Plan* document, which should instead be based on independent advice from NESO.

On 13 December 2024 DESNZ published the *Clean Power 2030 Action Plan*, including a Connections Reform Annex which included clear regional targets for the maximum capacities for different types of energy generation, including solar, on the transmission network, as advised by NESO.

5. Further Lobbying by Solar Developers – open letter to Secretary of State for DESNZ

On 7 February 2025 solar industry trade group Solar Energy UK wrote an open letter to the Secretary of State for ESNZ urging him to raise the regionally capped targets for

both solar connected to the transmission grid and Battery Energy Storage Systems, which were also hugely oversupplied in the pipeline.

The letter also added: 'We would also ask if there are any mechanisms in place for government to hold NESO accountable, to avoid these contradictions repeating again in the future.'

(Letter reported here: https://www.solarpowerportal.co.uk/solar-investment/solar-energy-uk-capping-solar-and-bess-risks-26-billion-investment)

NESO is supposed to advise the government as an expert independent body. Its advice should not be impacted by industry lobbying.

6. **Minister for Energy writes to NESO to change their regional solar targets**

On 7 April 2025, the Minister for Energy (who was copied into the 3rd December 2024 letter to the Secretary of State for ESNZ) writes to NESO that the government is changing NESO's 'independent' advice to address a 'misalignment between solar capacity allocations and the solar pipeline for 2031 to 2035'. They are changing the targets because there are more transmission solar projects in the pipeline than NESO advises are required.

PDF

Clean Power 2030 Action Plan: solar capacity update - letter to NESO, 7 April 2025

PDF, 103 KB, 2 pages

Details

The Minister for Energy has written to the National Energy System Operator (NESO) to advise that government is republishing the connections reform annex of the Clean Power 2030 Action Plan. The update is intended to address a misalignment between solar capacity allocations and the solar pipeline for 2031 to 2035.

This technical update will enable NESO to allocate network capacity to the most well-developed solar projects across transmission and distribution in each region. The overall solar capacity allocation remains as in the original publication.

Published 7 April 2025

[redacted]

CC: [redacted]Ofgem
7 April 2025

Dear [redacted]
I am writing to advise that government is today republishing the Connections Reform Annex of the Clean Power 2030 Action Plan (CPAP) to address a misalignment between solar capacity allocations and the solar pipeline for 2031 to 2035[footnote 1]. The misalignment has come about because the recent trend of increased solar project pipeline at transmission was not fully reflected in National Energy System Operator's (NESO's) 2024 Future Energy Scenarios, on which NESO's Clean Power 2030 advice to us was based.
My department has engaged extensively with Ofgem, NESO, and stakeholders on this issue and it has become clear that the flexibilities included within NESO's connection reform proposals, currently being considered by Ofgem, are not the most appropriate way to correct the misalignment. We have therefore decided to address it by amalgamating the CPAP solar distribution and transmission allocations for 2031 to 2035 (see tables 2 and 4 in the republished Connections Reform Annex). This will ensure that the most well-developed solar projects across both Transmission and Distribution are allocated the capacity available in their region.
This is a one-off technical update to the CPAP in response to a particular development in the underpinning evidence, with the overall solar capacity allocation remaining the same as on initial publication. I should note that we have fully considered other stakeholder concerns with CPAPallocations and are satisfied that the solar allocation for the 2031-35 period is the only area where the evidence underpinning the CPAP has changed significantly.
As such, we have made no other changes to the CPAP and we do not expect to revisit allocations again until the publication of the Strategic Spatial Energy Plan (SSEP) in late 2026. As set out previously, the 2031 to 2035 figures in the Annex are interim and are subject to updates through the SSEP, noting that the SSEP will not change any connection agreements issued prior to its publication.
Increasing the overall capacity allocations for 2031 to 2035 for any technology would reduce the scope for the SSEP to optimise the future network, by considering the most cost-effective spatial optimisation of different technologies in a holistic way.
As ever, I am extremely grateful for your close collaboration on this critical endeavour.
I am copying this letter to [redacted]
Yours ever,

[redacted]
Minister for Energy

Ofgem make clear that it was the government, not them or NESO, that updated the Connections Reform Annex, that this was to address a 'misalignment' between the number of projects in the solar pipeline and the existing solar capacity allocations, and that the amalgamation of distribution and transmission zones for 2031-2035 allows for the permeability requested by 'some respondents' (Summary Decision Document:TMO4+ Connections Reform Proposals – Code Modifications, Methodologies & Impact Assessment, 15 April 2025, p. 75, 7.52 - see screenshot below).

There is no indication in this document or any previous one by NESO or Ofgem that it is they who advise the amalgamation of transmission and distribution zones and targets on the basis of new evidence. There is no publicly available report revealing the Energy Minister's quoted 'particular development in the underpinning evidence'. If the evidence has changed, this change should have been published by NESO and Ofgem. However, Ofgem does not say that this change is due to a change in evidence about the need for additional transmission-connected solar, but only to 'the permeability requested by some respondents.'

7.52 **Solar capacities** – the Government updated the Connections Reform Annex of the CP2030 Action Plan on 7 April 2025 to address a misalignment between solar capacity allocations and the solar pipeline for 2031-35. The amalgamated transmission and distribution zones for 2031-35 allow for the permeability requested by some respondents.

7. The new regional targets: distribution plus transmission

The Connections Reform Annex of the Clean Power 2030 Action Plan was republished by NESO on 7 April 2025. Exactly as the solar developers demanded in their private lobbying letter to the Secretary of State for ESNZ in December, the *Connections Reform Annex of the Clean Power 2030 Action Plan* revises the regional solar targets to combine both distribution and transmission targets (written as Tx + Dx).

Clean Power 2030 Action Plan: Connections reform annex (updated)

Table 6: Regional capacity breakdowns for technologies with amalgamated transmission and distribution network capacities for 2035

Transmission network region name	Transmission network region code	Tx + Dx Solar (MW) 2035	Tx + Dx Onshore wind (MW) 2035
N. Scotland	T1	2,500	-
S. Scotland	T2	2,600	-
Scotland total		**5,100**	**21,200**
N. England	T3	5,200	-
N. Wales, the Mersey and the Humber	T4	9,500	-
Midlands	T5	13,700	-
Central England	T6	9,500	-
E. Anglia	T7	3,300	-
S. Wales and the Severn	T8	8,300	-
S.W. England	T9	5,500	-
S. England	T10	2,300	-
South East England	T11	7,000	-
England and Wales total		**64,200**	**15,800**
GB total		**69,400**	**37,000**

Note: MW capacity figures have been rounded to the nearest 100 MW.

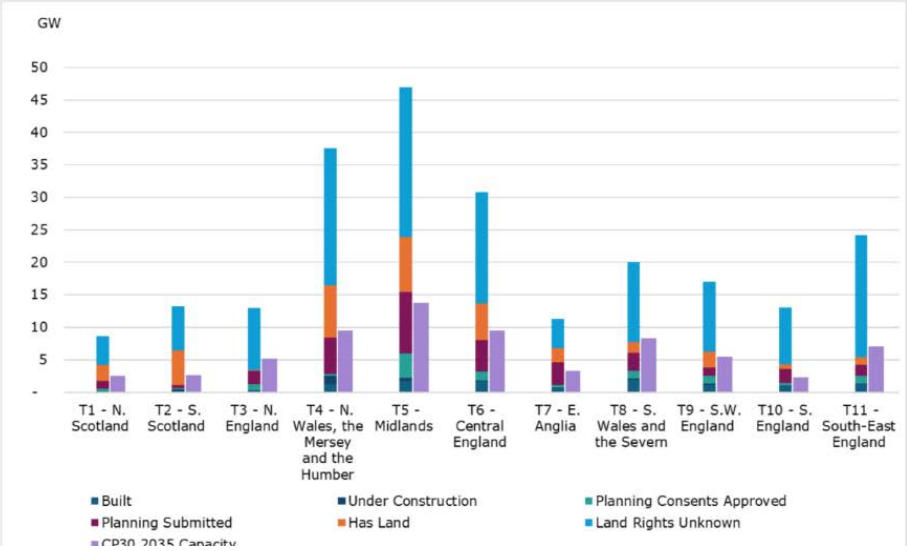
Again, looking at the case of East Anglia, the regional target for solar has gone from 900MW in 2035 in the first version of Clean Power 2030, to 3,300MW in the revised April 2025 version by no longer making a distinction between transmission and distribution, just as the transmission solar developers had demanded.

NESO grants transmission grid connections on the basis of alignment with these regional targets. This means that after private lobbying from Island Green Power to combine the distribution and transmission targets, which DESNZ has done, both of Island Green Power's 1GW excess transmission solar projects in Norfolk will now be measured in terms of 'alignment' against the new 3,300 MW target set by DESNZ whom they have directly lobbied to do this. This is against NESO's theoretically 'independent' advice that only 900MW of transmission solar is required across the whole of East Anglia to meet the 2035 solar target.

8. Unexpected Outcome

On 15 April 2025, Ofgem carried out an analysis of the solar pipeline across both distribution and transmission networks (*TMO4+ Impact Assessment*).

Figure 25 Comparison of the combined distribution and transmission queue of solar projects in each transmission zone to CP2030 Action Plan 2035 permitted capacities (GW)



Their research revealed that as of that month, in East Anglia, even the combined distribution and transmission maximum capacities (the lilac bar) had already been met by solar projects either consented or already in planning. So despite Island Green Power's private lobbying in December 2024, and DESNZ's resulting update of the 'Connections Reform Annex' to combine distribution and transmission maximum capacities as IGP had requested, their two Norfolk NSIP solar projects are still in excess of the new regional targets and should still not receive gate 2 grid connections

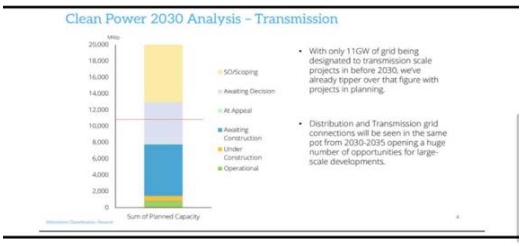
under NESO's 'ready and aligned' methodology. With no need for these projects to meet 2035 targets and no gate 2 grid connections, these projects should not be given development consent by the Secretary of State for ESNZ.

This excess supply of solar projects even against the Tx + Dx combined targets is also evident in other regions of the UK: by April 2025 the Midlands had already more than met its 2035 maximum capacity target by projects already consented or in planning (this region is particularly badly hit by the cumulative impact of many of these huge solar NSIP projects). The South of England had also already met its 2035 capacity target by April 2025.

9. A transmission gold-rush

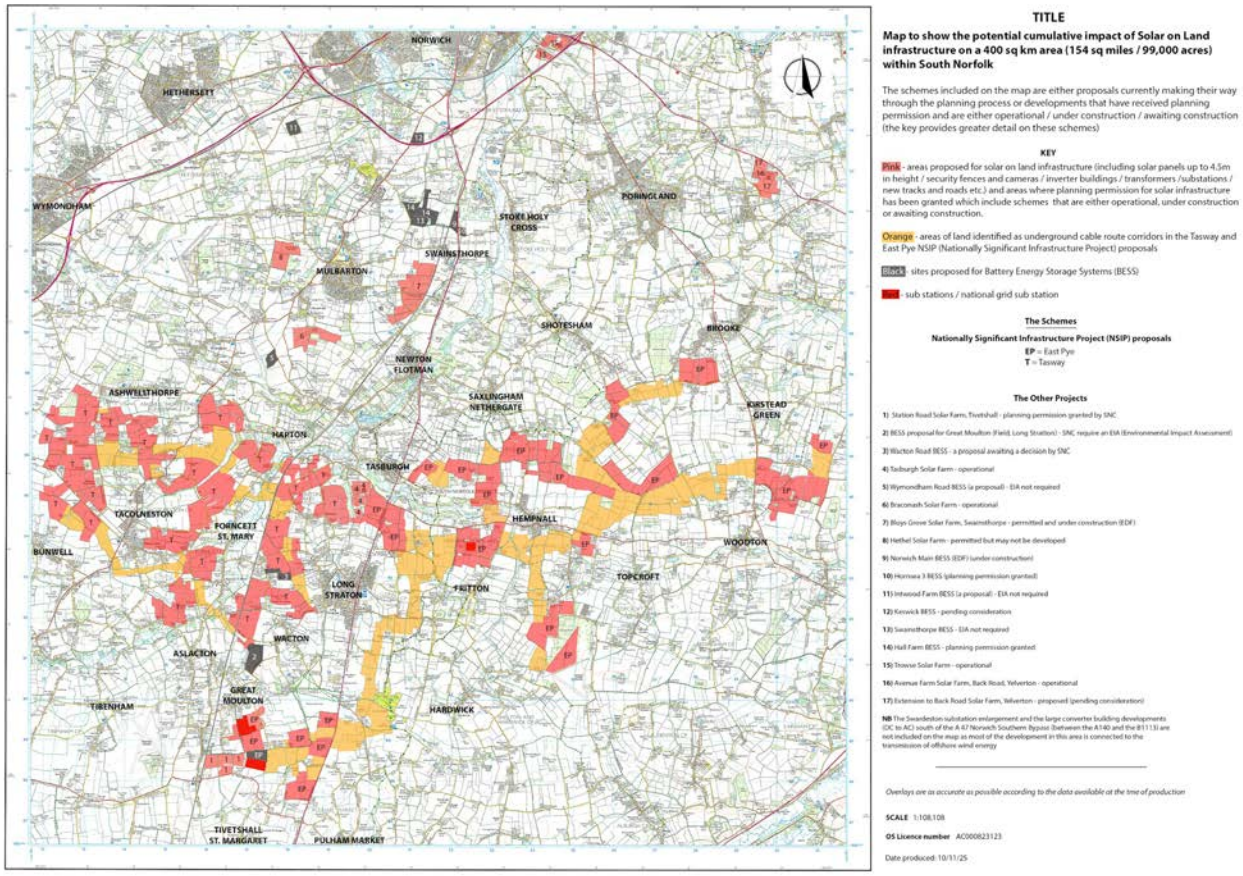
The result of DESNZ combining the transmission and distribution targets was that developers of vast NSIP solar infrastructure then saw this as an opportunity to propose even more excess transmission projects.

During the webinar 'Making large scale solar worth it: Delivering the UK's first solar NSIP' (19 June 20205) by Rosalind Smith Maxwell of Quinbrook Infrastructure Partners (the new owners of Cleve Hill Solar NSIP across 800 acres in Kent, now renamed 'Project Fortress') and analyst Josh Cornes on the Solar Power Portal, Cornes makes it clear that: "Although things are tight for the next four and a half years, post 2030 there's huge potential for large-scale solar; with the announcement that distribution and transmission connected projects will fall into the same pot [for grid connections], transmission scale developers have definitely been heard." Transmission projects were severely limited under the previous CP2030 regional targets but now the transmission and distribution capacities have been combined, this opens opportunities for even more large-scale transmission developments, which were considered unnecessary under the previous 'independent' advice from NESO.



Quote:' Distribution and Transmission grid connections will be seen in the same pot from 2030-2035 opening a huge number of opportunities for large scale developments.'

The negative impact on the landscape, soil, wildlife and local communities of this type of utility scale solar infrastructure can be seen from Cleve Hill/Project Fortress in Kent, now that construction is complete. This scheme is only 800 acres, whereas most NSIPs now going for consent are over 2,500 acres. Some, which adjoin other projects, such as Tasway (Aukera) and East Pye Solar (Island Green Power) can cover 6,500 acres in solar infrastructure - potentially double that if including cable corridors) - engulfing Domesday Book Conservation villages, Norman Churches, Chalk streams and several hundreds of Listed Buildings in their path, across 17 miles of pristine countryside.



These NSIP projects are also granted Compulsory Purchase Powers, potentially threatening private land ownership and local businesses in their paths.

Stop Oversized Solar
Community groups opposing Nationally Significant Infrastructure Project (NSIP) solar proposals in Anglesey, Bedfordshire, Buckinghamshire, Cambridgeshire, Kent, Lincolnshire, Norfolk, Northamptonshire, Nottinghamshire, Suffolk, Wiltshire and Yorkshire: Block East Pye Solar • Claydons Solar Action Group • East Riding Against Solar Expansion • Fields of Glass • Grwp Cadw Tir Môn • Hands Off Our Marsh • Kingsway Solar Community Action • Mallard Pass Action Group • Say No to One Earth Solar Farm • Say No To Sunnica • 7000 Acres • Springwell Solar Action Group • Stop East Park Energy • Stop Greenhill Solar • Stop Lime Down • Stop Mylen Leah • Villages Against Solar Threat

This is not the type of infrastructure that should be routinely sited around our ancient rural villages and surrounding people's homes. In her webinar, [redacted] claimed we need 85 Cleve Hills to meet the Government's targets.

10. **The Secretary of State makes the final decision on NSIP (transmission) solar development consent orders**

    The Secretary of State for ESNZ makes the final decision on whether these Transmission-connected solar NSIP projects should be given development consent. His department's own correspondence states that he should not respond to comments on specific concerns about projects: 'Given the quasi-judicial role of the Secretary of State in determining any such applications, it would not be appropriate to comment on specific concerns regarding the proposal as this could be seen as prejudicing the decision-making process.' (Letter from DESNZ 22 November 2024).

Despite this written acknowledgement to residents, the Secretary of State did engage directly with developers on their specific concerns.

The solar developers lobbied the Secretary of State in December 2024 to combine the transmission and distribution regional solar targets so that their transmission projects would still get gate 2 grid connection despite being in excess of 'independent' NESO's regional targets.

In April 2025 the Department for Energy Security and Net Zero updated NESO's 'Clean Power 2030 Connections Reform Annex' to reflect exactly what the solar developers had asked them to do in their lobbying letter in December 2024. It would appear in DESNZ's own words that the 'decision-making process' is very much prejudiced by this engagement with the solar industry on their 'specific concerns'.

This sequence compromises the appearance of impartiality, potentially breaching Nolan Principles of objectivity, as the Secretary of State appears to be compromised by industry lobbying by the very companies whose projects he will be required to independently judge in his 'quasi-judicial role'.

It also appears that the Department of Energy Security and Net Zero, may have compromised the independence of 'NESO' by updating its supposedly 'independent' advice to exactly reflect the demands made of them by the solar industry in their lobbying letter. No independent evidence on which this decision has been made has been published in any source we are able to locate. Presenting NESO's advice as independent risks misleading the public, given this ministerial direction.

11. Impartiality appears to be compromised

The Secretary of State for ESNZ's and Energy Minister's adoption of the developers' position following lobbying raises concerns about procedural fairness, and appears to compromise the independence of both NESO's gate-allocation process, as well as DESNZ's decision-making process, a sequence giving rise to an appearance bias under the fair-minded observer test (Porter v Magill [2001] UKHL 67). Neither the Secretary of State, nor the Minister for Energy, should be making decisions on the granting of development consent to NSIP solar projects, as this gives rise to an appearance of conflict of interest, contrary to Ministerial Code.

‘When Ministers are taking decisions in a quasi-judicial capacity they are expected to take particular care to ensure that their actions are impartial, and that they are seen to be so.’ (Ministerial Code, 8.4)

By altering NESO’s advice following direct lobbying from parties with live NSIP applications, and then determining those applications himself, the Secretary of State acted inconsistently with §8.4 of the Ministerial Code.

Evidence of the solar developers’ direct lobbying of the Secretary of State for ESNZ and the Energy Minister to inflate regional targets for ‘alignment’ by combining transmission and distribution targets contravenes the principle that policy decisions must be made free from developer influence. If the Secretary of State or the Minister for Energy rely on those altered targets when determining DCOs – for example because the solar NSIP is now ‘viable’ because it has a gate 2 transmission connection offer from NESO when it would not previously have been given one - the decision would be tainted by apparent bias and irrational (Associated Provincial Picture Houses v Wednesbury [1948]).
The rule of law requires that the Secretary of State act as an independent arbiter, not with the appearance as a party to an industry campaign.

Nolan Principles definitions (as currently stated by the *Committee on Standards in Public Life*, updated 2023).

Integrity
‘Holders of public office must not place themselves under any financial or other obligation to outside individuals or organisations that might seek to influence them in the performance of their official duties.’

Objectivity
‘Holders of public office must act and take decisions impartially, fairly and on merit, using the best evidence and without discrimination or bias.’

Honesty
‘Holders of public office should be truthful.’

Any public presentation of NESO's revised advice as 'independent' is misleading to the public when it has been altered according to ministerial direction.

By intervening to alter NESO's independent advice on regional solar capacity targets after private lobbying by developers with live NSIP applications, the Secretary of State and Minister for Energy have acted in a way that creates a *reasonable perception of bias* and conflicts with both these clauses. Their conduct gives the appearance that outside interests have influenced departmental policy in a domain where the Secretary of State subsequently acts in a quasi-judicial capacity as final decision-maker on those same developers' projects. This gives rise to an apparent conflict of interest, contrary to Ministerial Code para 7.1. The appearance of pre-determination and apparent bias undermines public confidence in the integrity of the NSIP decision-making process and taints any subsequent determinations under the principles established in *Porter v Magill [2001] UKHL 67* and *R (Alconbury Developments Ltd) v Secretary of State for the Environment [2001] UKHL 23*.

By engaging in direct correspondence and meetings with solar developers whose projects fall to be determined under the Secretary of State's quasi-judicial powers, and by subsequently altering NESO's supposedly independent advice to reflect those developers' demands, both the Secretary of State for Energy Security and Net Zero and the Minister for Energy appear to have acted in a manner inconsistent with these principles. They appear to have placed themselves under an obligation—whether real or perceived—to the very organisations seeking government approval for their own schemes, thereby compromising integrity. In directing changes to NESO's regional solar targets contrary to its own evidence-based recommendations, they appear to have have failed to act objectively or to base decisions on 'the best evidence, without bias.' The resulting loss of impartiality gives rise to an appearance of bias within the meaning of *Porter v Magill [2001] UKHL 67*. The Secretary of State and Energy Minister's personal involvement in altering NESO's advice to match developers' demands would lead a fair-minded and informed observer to conclude there was a real possibility of bias (*Porter v Magill*, *Lewis v Redcar*).

Potential Breach of Statutory Independence under the Electricity Act 1989

Under Section 47 of the Electricity Act 1989, the Gas and Electricity Markets Authority (Ofgem) — and by extension the National Energy System Operator acting under its

regulatory framework — is required to exercise its functions 'independent of any Minister of the Crown' in the regulation of electricity generation, transmission and distribution. The statutory purpose of this independence is to ensure that the operation of the national grid, and the allocation of transmission connections, are governed by objective technical and economic criteria rather than political or commercial influence.

By issuing directions to the National Energy System Operator to alter its independent *Clean Power 2030* advice and regional capacity targets following lobbying from solar developers, the Department for Energy Security and Net Zero appears to have effectively interfered with a function Parliament intended to be exercised independently of Ministers. This interference appears to undermine Ofgem's statutory duty to regulate the transmission queue objectively, compromise the integrity of the gate-allocation process, and give rise to a perception of lack of impartiality, inconsistent with both the Electricity Act 1989 and the Ministerial Code. (See *R (v Director General of Telecommunications, ex p Cellcom Ltd)* [1999] EWHC Admin 1367 – where excessive industry influence on a regulator was held to constitute regulatory capture and breach of statutory duty).

Recommended Remedy and Parliamentary Oversight

To restore confidence in the independence of energy-system governance, Ofgem should immediately reaffirm the autonomy of the National Energy System Operator by re-adopting NESO's original December 2024 regional transmission-capacity targets and confirming that all future advice to government will be issued free from ministerial instruction or approval.

The evidence from Ofgem and NESO on which DESNZ relied to make the change to the regional targets (by combining Tx + Dx) should be published to demonstrate that it was not merely on the basis of lobbying by solar developers of transmission-connected projects.

The House of Commons Business and Trade Committee (formerly BEIS Committee) should be invited to examine whether the Department for Energy Security and Net Zero's actions constituted an unlawful ministerial direction under the *Electricity Act 1989* and whether safeguards are required to prevent similar interference. Until such

independence is re-established, any Development Consent Order determined by the Secretary of State or the Minister for Energy that relies upon the altered April 2025 *Clean Power 2030* targets will remain open to challenge on grounds of apparent bias and procedural unfairness.

12. The Test

As previously noted, according to Ofgem's analysis in April 2025, the two Island Green Power projects in Norfolk in the East Anglia region (including East Pye Solar shown in the map on page 15) should not receive gate 2 transmission grid connections as they are in excess of the Clean Power 2030 Action Plan's combined distribution and transmission targets for 2035. In its *TM04+ Impact Assessment* Ofgem states: 'we estimate that in the Midlands, South England, and East Anglia transmission regions all solar projects with land rights only will receive a Gate 1 offer' (2.128)

NESO announced on 17 October 2025 that only a third of projects in the pipeline would receive gate 2 connection offers. If NESO truly independently follows its own 'ready and aligned' methodology, these two Island Green Power solar NSIP projects should not receive gate 2 grid connections. They should also therefore not receive development consent from the Secretary of State for ESNZ because they are in excess of the combined transmission and distribution targets for the region, resulting in unnecessary grid congestion and the need to be regularly 'constrained off', causing additional expense for consumers. There will be no benefit to be gained from the harms they will cause to the landscape, heritage, wildlife and communities they encircle. Granting consent to these two projects would directly undermine the government's Clean Power 2030 reforms and the gate 2 process that the Secretary of State has personally endorsed.

If these two Island Green Power projects in East Anglia receive gate 2 grid connections and development consent, they would potentially be open to legal challenge, as would the independence of the Secretary of State as the final arbiter of the NSIP process in light of the evidence above.

stop.oversized.solar.uk@gmail.com

Timeline Summary

- **5 July 2024** [redacted] MP is appointed Secretary of State for Energy Security and Net Zero

- **12 July 2024** [redacted] MP, Secretary of State for Energy Security and Net Zero, approves three NSIP solar projects connecting to the transmission network, in his quasi-judicial role as final decision-maker: Mallard Pass Solar Farm (Recurrent Energy (Canadian Solar) and Windel Energy) Gate Burton Energy Park (Low Carbon/EDF Power Solutions UK) Sunnica Energy Farm (Tribus Clean Energy and PS Renewables) which the Planning Inspectorate has advised should not be given development consent.

- **Summer of 2024** - It is already apparent to NESO and DESNZ that there are far more solar and battery projects in the Transmission connection pipeline than are necessary to meet even the UK's projected need for 2050.

- **5 November 2024**, NESO publishes independent advice *Clean Power 2030: Advice on achieving Clean Power for Great Britain*, submitted to DESNZ. NESO sets out draft documents for a connection reform process including the gate 2 'ready and aligned' criteria. They also provide draft analysis of the solar transmission queue both on a national level and in different regions in relation to the Clean Power 2030 and 2035 maximum permitted capacities.

- **22 November 2024** DESNZ writes that any comments by the Secretary of State about specific concerns regarding solar NSIP proposals could be seen as prejudicing the decision-making process given his quasi-judicial role: 'Given the quasi-judicial role of the Secretary of State in determining any such applications, it would not be appropriate to comment on specific concerns regarding the proposal as this could be seen as prejudicing the decision-making process.' (Letter to South Norfolk Constituent about a local NSIP transmission Solar Project from DESNZ).

- **December 2024**, NESO publishes their analysis of the solar transmission queue both on a national level and in different regions in relation to the Clean Power 2030 and 2035 maximum permitted capacities (*NESO Connections Reform Data Impact*

Assessment, December 2024). It is apparent that there are already more than enough solar projects with consent or in planning to more than meet the national maximum transmission targets for both 2030 and 2035. There are also adequate solar projects in the distribution pipeline to meet 2030 maximum capacity and to almost meet the 2035 maximum capacity. Projects exceeding these targets would not receive secure grid connections.

- **3 December 2024**, Island Green Power, Enso Energy, Clearstone Energy and Innova write directly to Ed Miliband, the Secretary of State for ESNZ requesting an urgent meeting to discuss NESO's 'independent' advice to the government. 'We therefore urgently urge the government to reassess the allocation of solar across transmission and distribution, or remove the distinction between the two altogether.'
  They claim that there are inadequate projects in the distribution queue to meet the 2030 targets and therefore the excess transmission projects are needed. However, NESO's analysis above (figure 28) shows that this is not the case.

- **13 December 2024 DESNZ publishes *Clean Power 2030 Action Plan*, including a Connections Reform Annex** which includes clear regional targets for the maximum capacities for different types of energy generation, including solar, on the transmission network, as advised by NESO.

- DESNZ has also admitted through FOI that Island Green Power's 100% owner Australian bank Macquarie also lobbied DESNZ during this period about grid connections, sending letters on 28 November 2024, emails in December 2024 and January 2025, had a meeting on 13 January 2025, held a 'workshop' between Macquarie, DESNZ and NESO on 27 January 2025, and sent another letter to the Secretary of State for DESNZ on 15 May 2025.

- **24 January 2025** [redacted] MP, Secretary of State for Energy Security and Net Zero, approves NSIPs: West Burton Solar Project (Island Green Power/Macquarie); Heckington Fen Solar Park (Ecotricity).

- **7 February 2025** solar industry trade group Solar Energy UK writes an open letter to the Secretary of State for ESNZ urging him to raise the regionally capped targets for solar connected to the transmission grid.

- **7 April 2025,** the Minister for Energy (who was copied into the 3rd December 2024 solar lobbying letter to the Secretary of State for ESNZ) writes to NESO that the government is changing NESO's 'independent' advice in the *Connections Reform Annex* to address a 'misalignment between solar capacity allocations and the solar pipeline for 2031 to 2035'. They are changing the targets because there are more transmission solar projects in the pipeline than NESO independently advised are required.

- **7 April 2025** the Connections Reform Annex of the Clean Power 2030 Action Plan is republished by NESO to include regional maximum capacity targets that do not distinguish between distribution and transmission projects (Tx+Dx), just as the solar companies developing transmission projects had demanded in their lobbying letter of 3 December.

- **15 April 2025** NESO's new connections reform methodology is formally approved by Ofgem and published on a 'ready and aligned' basis. Excess transmission projects are now (in some regions) within the newly combined Tx+Dx maximum capacity targets – therefore 'aligned' and will now get secure (gate 2) grid connections, whereas previously these would not have been granted.

- **19 June 2025** [redacted] of Quinbrook Infrastructure Partners and analyst [redacted] in their webinar 'Making Large Scale Solar Worth it: Delivering the UK's First Solar NSIP' on the Solar Power Portal, make clear that transmission projects were severely limited under the previous CP2030 regional targets but that now the transmission and distribution capacities have been combined, this opens opportunities for even more large-scale transmission developments. "Although things are tight for the next four and a half years, post 2030 there's huge potential for large-scale solar; with the announcement that distribution and transmission connected projects will fall into the same pot [for grid connections], transmission scale developers have definitely been heard." These excess transmission projects were considered unnecessary under the previous 'independent' advice and analysis from NESO.

- **19 June 2025** [redacted] MP, Secretary of State for Energy Security and Net Zero, approves NSIP Oaklands Farm Solar Park (BayWa r.e. UK Ltd).

- **14 October 2025** [redacted] MP, Secretary of State for Energy Security and Net Zero, approves NSIP Tillbridge Solar Project (Tribus Clean Energy and Recurrent Energy)

- **17 October 2025** NESO announces that only a third of projects in the pipeline will receive gate 2 connection offers. We wait to see whether these are the ones that have directly lobbied DESNZ about grid connections.

It would appear in DESNZ's own words that the 'decision-making process' is potentially 'prejudiced' by the Secretary of State for Energy Security and Net Zero's engagement with the solar industry on their 'specific concerns' around NSIP solar projects that connect to the transmission network, on which he is the final decision-maker regarding development consent.

This sequence compromises the appearance of impartiality, potentially breaching Nolan Principles of objectivity, raising the question of whether the Secretary of State is able to make independent decisions on granting development consent to these NSIP solar projects.

The Department for Energy Security and Net Zero also appears to have compromised the independence of 'NESO' by updating its supposedly 'independent' advice to exactly reflect the demands made of it by the solar industry in their lobbying.

We wait to see whether NESO's allocation of gate 2 grid connections meets its own methodology or reflects lobbying of DESNZ by specific solar developers.

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Stop Oversized Solar
Community groups opposing Nationally Significant Infrastructure Project (NSIP) solar proposals in Anglesey, Bedfordshire, Buckinghamshire, Cambridgeshire, Kent, Lincolnshire, Norfolk, Northamptonshire, Nottinghamshire, Suffolk, Wiltshire and Yorkshire: Block East Pye Solar • Claydons Solar Action Group • East Riding Against Solar Expansion • Fields of Glass • Grwp Cadw Tir Môn • Hands Off Our Marsh • Kingsway Solar Community Action • Mallard Pass Action Group • Say No to One Earth Solar Farm • Say No To Sunnica • 7000 Acres • Springwell Solar Action Group • Stop East Park Energy • Stop Greenhill Solar • Stop Lime Down • Stop Mylen Leah • Villages Against Solar Threat

OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: 08 January 2025 16:55
To: [REDACTED:12(3)]@energysecurity.gov.uk [REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@energysecurity.gov.uk ; [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@macquarie.com
Subject: Follow up meeting - Macquarie feedback to Clean Power 2030 Action Plan

OFFICIAL

Hi [REDACTED:12(3)],

Happy new year to you and the team, hope you had a restful Christmas holiday.

As promised, we wanted to pass on our more elaborated feedback to the CP 2030 Action Plan and kindly ask for a follow up meeting to discuss this in more detail, ideally with you and Alok again, and if possible Chris Stark as well.

Given the tight timelines and the potential impact explained below, if we could meet early next week that would be hugely appreciated on our side if you think that would be feasible?

First of all, the plan published by the Government is positive and its ambition is welcomed. In particular, it helps clarify the Government's intentions and helps set a strong direction for us to make future investments in the UK. When reading deeper into the CP30 document published, however, there are several points which could potentially put at risk the investment into projects that are capable of helping the Government achieve its goals by 2030.

Focusing on IGP, our largest UK based solar & BESS developer, we have a portfolio of 10+ GW which can support the Government's 2030 and 2035 ambitions. Of these projects we have 9 projects totalling 5.2 GW (of which 1.5 GW can be connected by 2030) that are now at risk due to capacity/technological limits applied in certain zones published in the CP 30 Annex. It should be noted that almost all of these projects have grid offers which we are currently being paid for (including securities), have secured land, and are currently being invested in to progress planning. We would like to work collaboratively with the Government to understand if there is a way to clarify certain points and enable further investments into these projects.

Please see the items we are keen to better understand and clarify following the publication of the Action Plan:

A. *Flexibility around the published zonal and technological capacity limits*

    I. *How did DESNZ come to the Zonal and overall GB-wide Capacity Caps?*

II. *Is it foreseen that projects which have sufficient readiness and existing near-term grid offers to not receive Gate 2 grid offers as a result of the Capacity caps?*

III. *In circumstances where there are multiple projects capable of meeting Gate 2 but their capacity is above the stated limit, how will those projects be treated? Key questions around this are:*

- *How flexible are the caps that have been allocated by technology per zone and per GB overall?*
- *How flexible are the caps that have been allocated by Capacity per zone and per GB overall?*

IV. *How will you approach shifting allocation between Distribution and Transmission?*

- *Is there a general intention to push projects from Transmission to Distribution even if it results in perverse outcomes (i.e. higher cost of electricity due to higher installed costs) or is there a specific rationale associated with the limits published in CP30?*
- *How will you approach circumstances where in similar zones Transmission is oversubscribed and Distribution is undersubscribed?*

B. *Grid Securities:*

I. *If a project is delayed or loses its queue position due to this reform, will developers have the chance to receive back any grid securities issued for the previous grid connection?*

C. *Clarifying the process and timetables*

I. *Will there be further written clarification on how the execution of CP30 plan will work – if so when is that expected?*

II. *Are there expected updates to the readiness criteria or compliance requirements for Gate 2 submissions?*

I look forward to hearing from you and please let me know if you have any questions.

Many thanks,

[REDACTED:12(3)]

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OFFICIAL

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Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Hi [REDACTED:12(3)],

Many thanks for sending this across, and I'll pass this on to relevant colleagues.

As you suggested, once the team has reviewed the report in more detail, a further discussion in January sounds sensible. I'm on leave until the 2nd (along with many colleagues) so I suggest we pick up week commencing 6th.

It has been a pleasure working with you over the last year, and I look forward to building on this in 2025.

Wishing you a Merry Christmas and have a nice break.

[REDACTED:12(3)]

Department for Energy Security & Net Zero

[REDACTED:12(3)]

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Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Hi [REDACTED:12(3)],

Apologies for the delay in sending our first reaction to the published Action Plan and thank you for sharing it with us under embargo, much appreciated.

The overall sentiment around the CP30 Action Plan grid reform changes remains negative for Macquarie at this point. Whilst we appreciate some level of deviation from the NESO report in the Action Plan, we feel it is not sufficient. The MAM team will review the AP in more detail after Christmas and perhaps we could organise another discussion in January to elaborate?

See some of the key concerns summarised by [REDACTED:12(3)] below and we're happy to follow up in the new year.

1. **Lack of Flexibility Across Transmission and Distribution Targets for Solar**
   The Government's allocation of 10.8GW of solar to Transmission and 36.2GW to Distribution, while slightly improved from NESO's initial recommendations, lacks the flexibility to maximise operational PV by 2030 and 2035. On the latest CPP targets, the Transmission queue is oversubscribed, whereas there is likely to be under-supply at the Distribution level. In addition, the distribution networks lack the capacity to add this volume on the network in such a short time frame which is why many projects have only been able to secure connections to the transmission network. We have not seen any evidence or data which demonstrates how the distribution network can deliver this volume of projects for 2035, however we are exploring this as a priority with other leading UK developers (inc. IGP) and looking to follow up in the NY. In addition, many Solar PV projects on the transmission network are often allocated distribution level voltages (eg 33kv and 132kv) and are likely to be removed from the queue because of a mere technicality of network ownership rather than for any particular economic or policy principle. This rigidity risks good quality Transmission-connected projects being cancelled or delayed.

2. **Insufficient Recognition of Co-Location Benefits**
   The omission of co-location's benefits in both the NESO's Clean Power 2030 advice and the Plan itself is concerning. Co-location can reduce costs, improve efficiency, and enhance investment attractiveness, yet there remains

little clarity on its future treatment. Current guidance restricts such projects unnecessarily, despite their potential to support grid resilience and consumer savings. I am keen to discuss ideas for how co-location could be recognised - for instance asset owners who are allocated a primary technology (e.g. solar or wind) of up to say 100MW, should be able to include 99.9MW of battery storage (without needing it to be aligned to Clean Power 2030) - because no additional infrastructure should be required and it helps keep costs down for consumers, investors and the system.

3. **Limited Protection for Investor Confidence**

   We appreciate the grandfathering of projects with CfD, Capacity Market contracts, or planning approval by May 2025 which offers some reassurance for near-term projects, however it leaves significant gaps for long-term investments. Large-scale NSIP projects with substantial upfront costs remain vulnerable, particularly those yet to secure final planning despite advanced stages of examination. Expanding protections to include projects in the examination phase of a DCO or DNS application by 20th December 2024 would alleviate some of this risk for these larger, well progressed and high profile projects.

I hope this helps as initial steer, wishing you and the team a great Christmas break and Happy New Year!

Best wishes,

[REDACTED:12(3)]

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To: [REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@energysecurity.gov.uk ; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

Hi [REDACTED:12(3)],

Apologies, hopefully final change!

[REDACTED:12(3)] will attend in person given [REDACTED:12(3)] can only join virtually now, can you please add him to the list of attendees for security? [REDACTED:12(3)] is a Managing Director at MAM GI and sits on the Board of Island Green Power so will be a good addition.

[REDACTED:12(3)], on the other hand, has a bad flu, so he won't attend.

Final list of in person attendees:

- [REDACTED:12(3)] (Macquarie Asset Management Green Investments)
- [REDACTED:12(3)] (Macquarie Asset Management Green Investments)
- [REDACTED:12(3)] (Macquarie Group)
- [REDACTED:12(3)] (Enso Energy)

Individuals who will try to dial in on Teams:

- [REDACTED:12(3)]
- [REDACTED:12(3)]

Many thanks,

[REDACTED:12(3)]

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Cc: [REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

Morning [REDACTED:12(3)] and all,

I just wanted to update that if you could please book a room with MS Teams available that would be much appreciated, as [REDACTED:12(3)] can no longer join in person (as he's been pulled into an investor meeting), but he would like to join virtually. As he'll be in between meetings, [REDACTED:12(3)] will also join online (he's based in Paris and also works in Macquarie Asset Management Green Investments).

Many thanks,

[REDACTED:12(3)]

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Cc: [REDACTED:12(3)]@energysecurity.gov.uk ;
[REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Many thanks [REDACTED:12(3)] most appreciated.

Yes, that will be all from our side (although we might bring one or two more in tbc).

Yep, please bring ID as will help speed through security. Happy to collect you all *

[REDACTED:12(3)]

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[REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Hi [REDACTED:12(3)] and team,

Absolutely, I was just waiting for the final version but please see attached:

- Letter to Ed Miliband MP sent on 3 December
- Enso Energy briefing note regarding the NESO advice summarising the key messages / asks

I hope this is helpful ahead of tomorrow.

If you could confirm final set of attendees on your side (Alok, you Chris and [REDACTED:12(3)] that would be great just so that we're on the same page.

In terms of practicalities, I assume we just need to show our ID and register at the reception where you will pick us up?

Many thanks and we look forward to speaking tomorrow.

Best wishes,

[REDACTED:12(3)]

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Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Hi [REDACTED:12(3)],

Hope you had a good weekend and thanks for this.

Could you send across the key points you wish to raise tomorrow when you have a moment? Been asked by a couple of colleagues on what the key themes will be...

[REDACTED:12(3)]

Department for Energy Security & Net Zero

[REDACTED:12(3)]

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Private Investment into Net Zero

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3-8 Whitehall Place

London, SW1A 2AW
www.gov.uk/desnz |

OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: 06 December 2024 15:48
To: [REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Hi [REDACTED:12(3)],

Confirming attendees from our side and their titles/positions:

- [redacted]: Managing Director and EMEA Origination for Macquarie Asset Management Green Investments (MAM GI); bio here.
- [REDACTED:12(3)] working on MAM GI asset Island Green Power (developer of renewable energy projects)
- [redacted]: Executive Director, Corporate Development, at Cero Generation (MAM portfolio company, solar energy developer)
- [redacted]: Managing Director at Enso Energy, bio here.
- [REDACTED:12(3)], Macquarie Group

As discussed, I will share the briefing document with you on Monday so that you have some time to scan through before the meeting.

Let me know if you have any questions and have a lovely weekend when it comes.

Best wishes,

[REDACTED:12(3)]

MACQUARIE

[REDACTED:12(3)]
Corporate Affairs | Macquarie Group Limited
Ropemaker Place, 28 Ropemaker Street, London EC2Y 9HD
M +44 [REDACTED:12(3)] | www.macquarie.com

OFFICIAL

From: [REDACTED:12(3)]@energysecurity.gov.uk
Sent: 06 December 2024 11:57
To: [REDACTED:12(3)]@macquarie.com
Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Great thanks [REDACTED:12(3)].

Department for Energy Security & Net Zero

[REDACTED:12(3)]

[REDACTED:12(3)]

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London, SW1A 2AW
www.gov.uk/desnz |

OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: 06 December 2024 11:31
To: [REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Hi [redacted],

Thank you checking regarding the slot, noted on Tuesday 2pm in person.

Appreciate your sending Alok's bio as well and will share with the team. I should be able to send our attendees and their titles by the end of today, and we'll share some background material on Monday so that you can all read before the meeting.

Many thanks,

[REDACTED:12(3)]

MACQUARIE

[REDACTED:12(3)]
Corporate Affairs | Macquarie Group Limited
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OFFICIAL

From: [REDACTED:12(3)]@energysecurity.gov.uk
Sent: 06 December 2024 11:21
To: [REDACTED:12(3)]@macquarie.com

Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Hey [REDACTED:12(3)],

As discussed, please find a short bio on [redacted] below:

[redacted] has spent the past decade in the Civil Service working across a range of roles, including in the Cabinet Office and No.10 on Brexit negotiations and in the Covid-19 Taskforce. More recently he has been the Deputy Director for Strategy in the Department for Energy Security and Net Zero and now the Deputy Director in the 2030 Clean Power Unit within 'Mission Control'.

Unfortunately, we can't bring the meeting earlier so let's stick to 14.00 if ok from your end. Be great if you can send us the list of names when you can.

Best,

[REDACTED:12(3)]

Department for Energy Security & Net Zero

[REDACTED:12(3)]

[REDACTED:12(3)]

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3-8 Whitehall Place

London, SW1A 2AW
www.gov.uk/desnz |

OFFICIAL

From: [REDACTED:12(3)]@energysecurity.gov.uk
Sent: 04 December 2024 12:32
To: [REDACTED:12(3)]@macquarie.com
Cc: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

Hi [REDACTED:12(3)],

Good to catch up earlier and apologies for the slight delay here.

After discussion internally, [redacted], deputy director in the clean power unit could make 14.00 next Tuesday (in person). Would that work from your side?

Best,

[REDACTED:12(3)]

OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: Tuesday, December 3, 2024 5:57:02 PM
To: [REDACTED:12(3)]@energysecurity.gov.uk
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Thanks [REDACTED:12(3)],

I assume it will be Thursday now, can I confirm that to colleagues for now? If you think you can get an update tomorrow morning I can hold off until then!

Many thanks,
[REDACTED:12(3)]

MACQUARIE

[REDACTED:12(3)]
Corporate Affairs | Macquarie Group Limited
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OFFICIAL

From: [REDACTED:12(3)]@energysecurity.gov.uk
Sent: 03 December 2024 09:12
To: [REDACTED:12(3)]@macquarie.com;
[REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk

Cc: [REDACTED:12(3)]@macquarie.com
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Morning [REDACTED:12(3)],

All good thank you!

Apologies for the slight delay here and this is in motion – just securing relevant colleagues.

Will confirm asap.

Best,

[REDACTED:12(3)]

Department for Energy Security & Net Zero

[REDACTED:12(3)]

[REDACTED:12(3)]

Private Investment into Net Zero

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www.gov.uk/desnz |

OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: 02 December 2024 19:45
To: [REDACTED:12(3)]@energysecurity.gov.uk ; [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@macquarie.com
Subject: Re: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Hi [REDACTED:12(3)] and [REDACTED:12(3)],

Hope you had a nice weekend.

I just wanted to check if there were any updates on which day/time would work for your colleagues?

Many thanks,

[REDACTED:12(3)]

Sent from Outlook for iOS

OFFICIAL

From: [REDACTED:12(3)]
Sent: Friday, November 29, 2024 5:14:38 PM
To: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk ; [REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@macquarie.com
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

Thanks [REDACTED:12(3)], that's helpful information for now and we can finalise on Monday.

Have a great weekend,

[REDACTED:12(3)]

MACQUARIE

[REDACTED:12(3)]
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M +44 [REDACTED:12(3)] | www.macquarie.com

From: [REDACTED:12(3)]@energysecurity.gov.uk
Sent: 29 November 2024 16:42
To: [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@energysecurity.gov.uk; [REDACTED:12(3)]@macquarie.com
Cc: [REDACTED:12(3)]@macquarie.com
Subject: Re: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Hi [REDACTED:12(3)],

The Clean Power Unit have confirmed [redacted] will not be available to join a meeting - but they are confirming who it would be, I imagine it will be either Deputy Director / Head of (G6) level but I'll confirm when I have an answer - hopefully that should give you some initial steer.

Best,

[REDACTED:12(3)]

OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: Friday, November 29, 2024 2:57:15 PM
To: [REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@macquarie.com
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

OFFICIAL

Hi [REDACTED:12(3)],

Thank you very much, if you could get an indication of attendees / format or preference for date by the end of today, please let me know and I'll update my colleagues who are preparing the materials for the meeting.

Best wishes,

[REDACTED:12(3)]

MACQUARIE

[REDACTED:12(3)]
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M +44 [REDACTED:12(3)] | www.macquarie.com

OFFICIAL

From: [REDACTED:12(3)]@energysecurity.gov.uk
Sent: 28 November 2024 23:06
To: [REDACTED:12(3)]@macquarie.com;
[REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk
Cc: [REDACTED:12(3)]@macquarie.com
Subject: RE: Investor and portfolio company feedback to NESO Clean Power 2030 report

External Communication

OFFICIAL

Thanks [REDACTED:12(3)],

Thank you for following up so promptly and I'm sure colleagues will welcome feedback.

We are just following up internally and will revert shortly.

Best,

[REDACTED:12(3)]

Department for Energy Security & Net Zero

[REDACTED:12(3)]

[REDACTED:12(3)]

Private Investment into Net Zero

Tel: +44 (0) [REDACTED:12(3)]
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OFFICIAL

From: [REDACTED:12(3)]@macquarie.com
Sent: 28 November 2024 12:04
To: [REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk;
[REDACTED:12(3)]@energysecurity.gov.uk Cc:
[REDACTED:12(3)]@macquarie.com
Subject: Investor and portfolio company feedback to NESO Clean Power 2030 report
Importance: High

Hi [REDACTED:12(3)], [REDACTED:12(3)], [REDACTED:12(3)],

I hope you're all doing well.

In our last monthly catch up you kindly mentioned that if we had feedback regarding the NESO Clean Power 2030 report, we should pass that onto you.

Some of our investment teams as well as our solar and energy storage portfolio companies have raised a few significant concerns about some of the NESO advice that may jeopardise investment, that they would like to make DESNZ aware of ahead of the Department's reaction to the NESO advice and before it starts being implemented.

We would therefore greatly welcome (preferably in-person but if impossible then virtual) meeting so that my colleagues and our portfolio company Cero can elaborate on this feedback. If you could let us know whether you could bring the relevant colleagues who are leading on the DESNZ response to the NESO guidance, that would be much appreciated, as we are conscious of the short timeframes for this.

Do let me know if we could arrange a meeting for next Tuesday, Wednesday or Thursday and who from DESNZ would be able to attend? I can then confirm on our side to ensure adequate seniority levels.

Many thanks,

[REDACTED:12(3)]

MACQUARIE

[REDACTED:12(3)]
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28 Ropemaker Street Facsimile +44 20 3037 2061 London EC2Y 9HD Internet
www.macquarie.com/uk United Kingdom

15 May 2025

Rt. Hon. [redacted] MP

Secretary of State Department for Energy and Net Zero

Department for Energy Security and Net Zero

55 Whitehall

London

SW1A 2HP

For the attention of [redacted] MP, Secretary of State Department for Energy and Net Zero

Dear Secretary of State,

Thank you for your co-signed 'Build it in Britain' letter of 24 April. Macquarie greatly appreciates the Government's ambitious targets, but we are facing a series of challenges on UK projects that could act to delay or block planned investment in the UK.

I have set out further information on our key areas of concern in an appendix to this letter. In summary, these relate to: the impact of Transmission Charging on the investability of offshore wind projects in the north of Scotland; the risk of implementing zonal pricing under Reform of Electricity Market Arrangements; Round 4 lease arrangements; and the need for grid connection reform to support the deployment of renewable generation and storage projects.

We would welcome an urgent meeting with you alongside Macquarie Asset Management's offshore wind development platform, Corio Generation, to discuss and find solutions to these challenges.

Yours sincerely,

[redacted]

Global Head of Macquarie Asset Management Green Investments .

Corio Generation – Resolving investment barriers to projects

Corio Generation are investing in almost 6 GW of offshore wind projects together with their partners, TotalEnergies, RIDG, Gulf and RWE. In the UK this includes our two strategic projects, Outer Dowsing Offshore Windfarm in England and West of Orkney Windfarm in Scotland, and our investment holdings in other major projects (Rampion 2 and Five Estuaries). While we are grateful for the steps taken by this government to support offshore wind power, significant uncertainty surrounding regulation and cost factors is seriously threatening key project investment decisions. This is leading developers like Corio to consider whether to delay planned development activities.

Unless urgent clarity can be provided on these key regulatory issues within the next 2 months, there is a significant risk that we will not be able to keep these projects on a delivery pathway for 2030 deployment:

The impact of Transmission Charging on the investability of offshore wind projects in the North of Scotland – the current Transmission Network Use of System (TNUoS) charging regime, combined with network loss costs (TLM) lead to a cost disadvantage of up to £25/MWh in CfD bid prices of offshore wind farms between the North of Scotland and Southern regions, significantly impacting the investment case for Northern projects as well as their competitiveness in a bidding round. We have called for Ofgem to implement a separate bidding round for Scotland as well as a robust cap and floor mechanism which would mitigate these impacts and reduce uncertainty for Scottish windfarms. Without an urgent remedy, TNUoS and TLM pose a critical risk for northern projects: At £25/MWh disadvantage, northern Scottish projects will be uncompetitive in an CfD auction

The future TNUoS is scenario driven and highly uncertain with significant impacts on project business cases. This level of uncertainty does not allow developers to continue spending on development and beyond to construction.

It is therefore critical that an appropriate cap and floor is urgently implemented to mitigate these risks and is guaranteed for a project's lifetime.

· **The risk of implementing Zonal Pricing under Reform of Electricity Market Arrangement (REMA) –** investment decisions for major infrastructure projects are being taken against the backdrop of significant regulatory uncertainty. Zonal pricing will introduce significant price risk and volume risk for projects and, without comprehensive legacy protection, these assets cannot assess their economic situation with sufficient accuracy and cannot continue to spend on development. We therefore ask that the Government provide developers, as a matter of priority, with much needed clarity on the legacy arrangements ahead of AR7 opening. Without clarity on legacy arrangements and the contractual mechanisms to implement these, the residual uncertainty does not provide developers and investors

with sufficient confidence in projects' economic viability and substantial development spending cannot be justified against that background.

· **Ensuring Round 4 lease arrangements support the delivery of project in line with Clean Power 2030 and beyond ambitions –** The Round 4 leasing auction was held against a very different economic reality and supply chain landscape than that of today, with the global offshore wind industry now facing unprecedented and unforeseen cost pressures on development companies and the supply chain. This changed reality presents a material risk for developers, as the projects are imminently approaching critical and irreversible decision points. [REDACTED:12(5)(f)]

[REDACTED:12(5)(f)] - Call for continued focus on grid connection reform

Separately, [REDACTED:12(5)(f)], has experienced issues on grid connections historically, and while we welcome the Government's work to reform the grid connection queues, which have significant ramifications to the UK development pipeline of generation and storage projects, more reform should be considered to speed up project delivery to avoid current impacts:

Project delivery - The impact of Statement or Works and Project Progression outcomes have led to uncertainty for developers, with some projects being connected quickly and others being cancelled, leading to a likely loss of development capital and other resource. Our development team has often been offered two-year DNO connection dates and six-year transmission connection dates, which twinned with delays for planning consents and three-to-five-year common land options, have resulted in many developers either pausing their 2035 connections to await confirmation on what queue ratification would mean for their projects, and others taking a more risk-based approach, progressing with their projects with the assumption that those projects that were most advanced would be connected first.

· **Expired planning permits -** These have led to negative impacts on the project delivery as different permissions run to different timelines, for example, [REDACTED:12(5)(f)] has often been provided 2037 connection dates on projects, which based on initial estimates, were due to take only two to three years to connect and whose land options and planning consents are due to expire in 2027, a decade prior to connection.

· **Procurement -** These delays are also impactful on materials and hardware resourcing and expenditure, as electrical switchgear and transformers take approximately three years to procure and cost millions of pounds in development costs, as are changes to the initial offered level of voltage for the connection, which can cause significant issues for the projects.

We wanted to raise these issues in the battery storage development sector to you and would ask for the Government to continue to work on reforming grid connections, planning, and permitting in order that developers and the investors that

underpin them, can look to avoid these delays and deliver projects that help support the Government's net zero and grid aims. [REDACTED:12(5)(f)], would be available to provide further information on these delays if that should be of use to DESNZ and the wider Government.

FOI-25-240 Response...

From: [redacted] (MAM)
To: [redacted] (Energy Security); [redacted] (Energy Security); [redacted] (NESO); [redacted]
Cc: [redacted] (MAM); [redacted] (MAM); [redacted] (MAM); [redacted]
Subject: [EXTERNAL] RE: Meeting on Monday - details and agenda
Date: 26 January 2025 20:24:14
Attachments: [redacted]

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Hi [redacted]

Apologies for sharing this late; however, we have worked with IGP on a presentation for tomorrow and believe a good way to navigate this discussion is to go through some specific projects in Zones T4-T8. We will be joined by [redacted] IGP, [redacted] who was on the previous call we had with DESNZ.

To do this we will walk through the following projects and the presentation attached live in the room.

Zone	Project Name	Customer Name	Grid Capacity (MW)	Connection Dates
T4	Monk Fryston (Light Valley Solar)	IGP Solar 18 Limited	500	Dec.30
T4	Thornton	IGP Solar 19 Limited	500	Oct.31
T5	Feckenham	IGP Solar 14 Limited	500	Jul.31
T5	Ironbridge	IGP Solar 16 Limited	600	Apr.31
T5	Rugeley	IGP Solar 17 Limited	600	Aug.31
T6	Grendon Solar & Bess (Green Hill)	Green Hill Solar Farm Limited	500	Oct.29
T6	The Droves	IGP International prospecting	500	Oct.33
T7	Long Stratton PV & Bess Station (East Pye)	IGP International prospecting	500	Oct.31
T8	Melksham (Lime Down)	Lime Down Solar Project Limited	500	Jul.30

Best regards,
[redacted]

From: [redacted] (MAM)
Sent: 25 January 2025 09:03
To: [redacted] (Energy Security) [redacted]@energysecurity.gov.uk>; [redacted] (Energy Security) [redacted]@energysecurity.gov.uk>; [redacted] (NESO) [redacted]@nationalenergyso.com>; [redacted]@macquarie.com>
Cc: [redacted] (MAM) [redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted]@macquarie.com>
Subject: RE: Meeting on Monday - details and agenda

Hi [redacted]

Good to e-meet you.

On Monday we will be presenting 12 IGP assets with a total capacity of 12GWs (7.2GW solar and 4.8GW BESS). [redacted]

We look forward to meeting you on Monday.

Best regards,
[redacted]

From: [redacted] (Energy Security) <[redacted]@energysecurity.gov.uk>
Sent: 24 January 2025 16:18
To: [redacted] Energy Security) <[redacted]@energysecurity.gov.uk>; [redacted] (NESO) [redacted]@nationalenergyso.com>; [redacted]@macquarie.com>
Cc: [redacted] (MAM) <[redacted]@macquarie.com>; [redacted] (MAM) < [redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted]@macquarie.com>
Subject: Re: Meeting on Monday - details and agenda

External Communication

OFFICIAL

This looks great thanks [redacted]

As mentioned previously can you confirm the projects in advance?

Best,

[redacted]

Sent from Outlook for iOS

OFFICIAL

From: [redacted]@macquarie.com>
Sent: Friday, January 24, 2025 4:13 pm
To: [redacted] (Energy Security) <[redacted]@energysecurity.gov.uk>; [redacted] (Energy Security) <[redacted]@energysecurity.gov.uk>; [redacted] (NESO) <[redacted]@nationalenergyso.com>
Cc: [redacted] (MAM) <[redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted] (MAM) <[redacted]@macquarie.com>; [redacted]@macquarie.com>
Subject: Meeting on Monday - details and agenda

Dear [redacted]

We look forward to our meeting on Monday at 11am, thank you all again for dedicating the time for chatting to us.

[redacted] as you're coming in person, please bring an ID, and [redacted] I'll send you a Zoom link separately that you can use.

In person attendees from our side will be [redacted] from Macquarie Asset Management Green Investments team (MAM GI), and [redacted] from the Government Affairs team.

In terms of the agenda for the meeting, we would propose the following rough structure:

- Introductions, Macquarie Group UK footprint and investment commitment, impacted portfolio companies
- MAM GI's understanding of the grid reform and latest guidance
  - Q&A discussion with NESO/DESNZ on any clarification points
- Deep dive into 3 case studies / assets of Island Green Power
  - More micro detail analysis of impact, planned projects and risks
  - Sense-checking of NESO's / DESNZ's thinking
- Next steps and any final Q&As

Please let me know if you have any questions, have a great weekend when it comes and see you on Monday.

Best wishes,
[redacted]

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[redacted]
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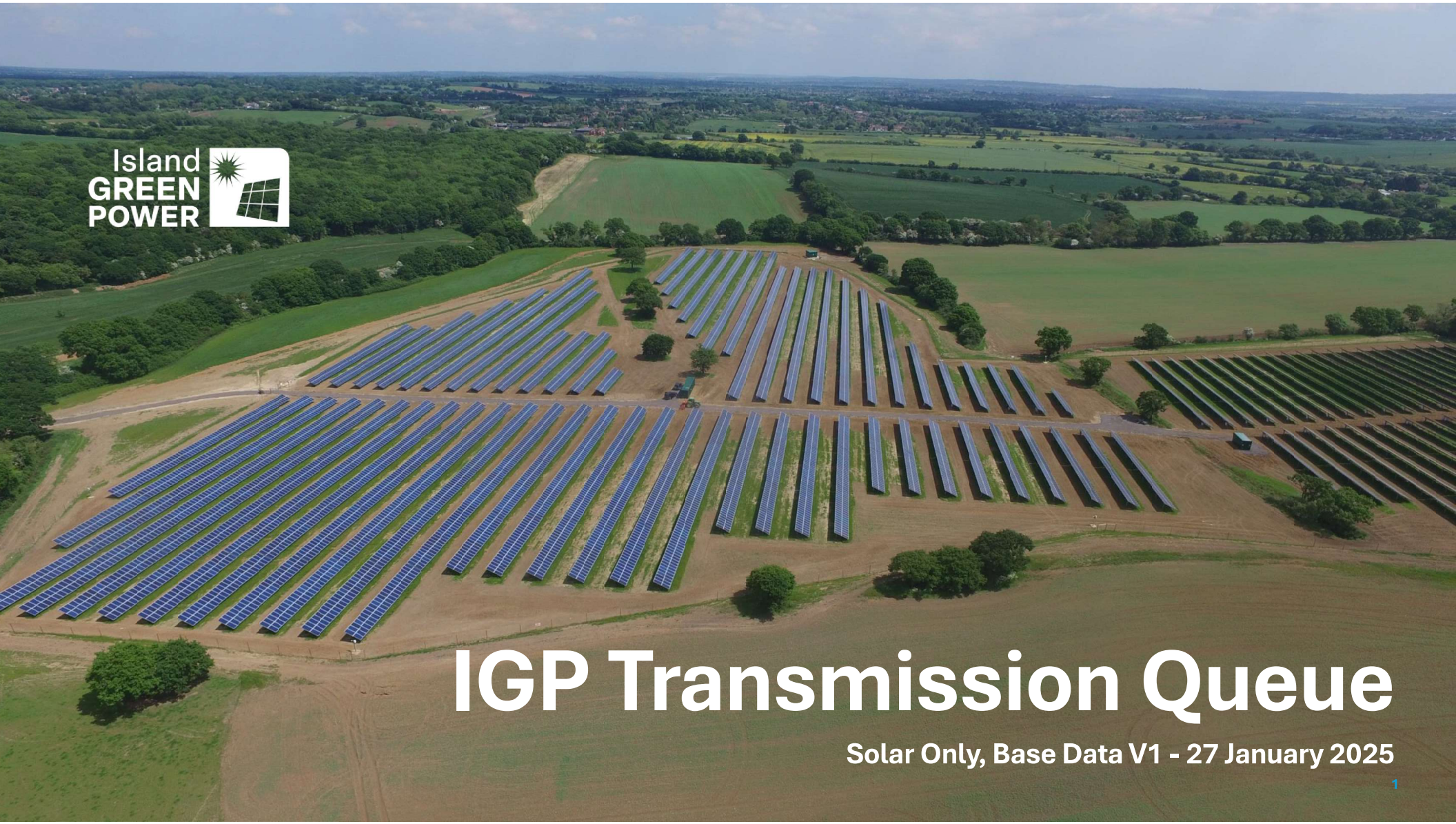


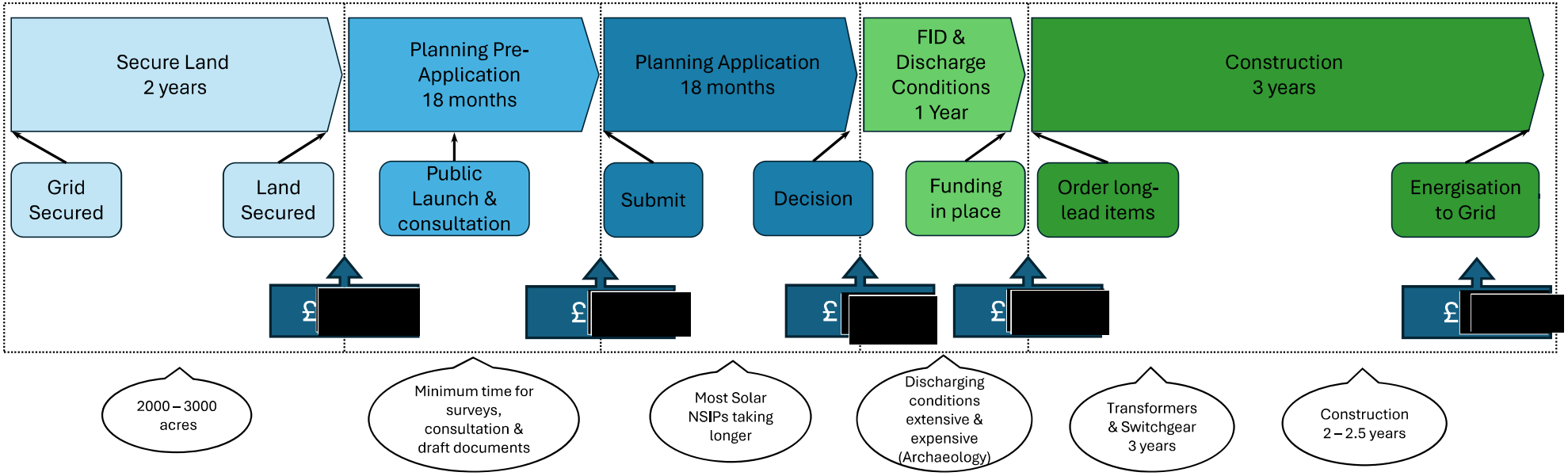
Island GREEN POWER

IGP Transmission Queue

Solar Only, Base Data V1 - 27 January 2025

1 – Solar NSIP Timeline

Based on historical projects; minimum time for each phase.

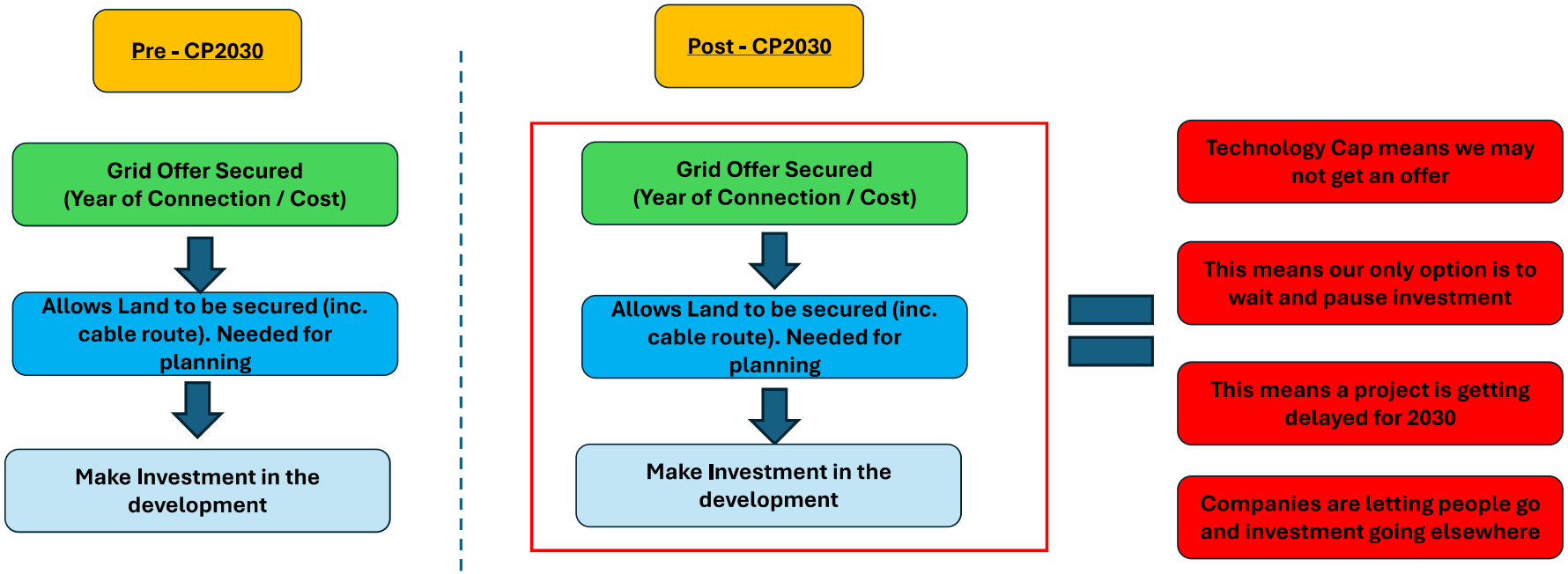


Certainty of grid connection critical now to continue investing and deliver on time for Net Zero:

- *Projects need to submit in 2025 to achieve 2030 connection dates – this should be considered in managing the queue.*
- *NSIP solar projects that have not started Planning Pre-Application won't connect until early 2030's*
- *Total timeline for projects with grid is up to 9 years*
- *Note that post decision archaeological trial trenching will cause significant delays and prevent delivery of multiple projects; lack of specialist capacity in the UK, expensive and not proportionate to impacts of solar. [redacted] Urgent review and guidance required.*

2 – IGP's Position – Negative Changes because of CP2030

CP2030 has forced is to consider if we delay investment.



- ***The industry was supportive of connection reform (removing zombie projects, re-ordering the que). Extensive consultation was done as part of connection reform.***
- ***On CP2030, very limited industry consultation (to none) was done on technology caps / transmission / distribution split. It was not a "hand in glove" approach.***
- ***The allocation transmission vs distribution only hurts real projects where people have invested (including people who are paying securities on a transmission level). It is also not a wait your turn approach it simply stops projects that could connect from advancing.***

3 – Case Study: Solar Transmission Queue for T7, [redacted]

[redacted]

3 – Solar Transmission Queue for T4 [redacted]

[redacted]

3 – Solar Transmission Queue for T5 [redacted]

[redacted]

3 – Solar Transmission Queue for T6

[redacted]

3 – Solar Transmission Queue for T8 [redacted]

[redacted]

Briefing Note

Macquarie, Island Green Power, DESNZ and the Clean Power 2030 solar connections changes

Introduction

FOI and EIR disclosures provide a clear picture of the lobbying that took place around the Clean Power 2030 grid-connections reforms in late 2024 and early 2025. The issue at the centre of the lobbying was the division between transmission-connected and distribution-connected solar. Under the original Clean Power 2030 framework, solar was strongly weighted towards distribution connection. For 2030, the national allocation was 10.8 GW of transmission-connected solar against 36.2 GW of distribution-connected solar. The original 2031–35 solar split was: Transmission-connected solar: 17.0 GW; Distribution-connected solar: 52.4 GW. Government also stated that renewables should connect to the distribution network wherever possible for reasons of 'speed and efficiency'. There were clear regional targets for distribution and transmission solar for both 2030 and 2031-2035 published in the Clean Power 2030 Action Plan.

For large transmission-connected developers, however, this created a serious commercial problem. Macquarie and IGP had a substantial portfolio of 500–600 MW projects seeking transmission connections across a number of regions. Macquarie told DESNZ that nine IGP projects totalling 5.2 GW were at risk under the original zonal and technology limits. In a letter of 3 December 2024, IGP asked DESNZ to combine the distribution and transmission targets. [Sources: NESO FOI-25-240, disclosed Macquarie correspondence; 3 December 2024 IGP/Enso/Clearstone/Innova letter disclosed under DESNZ EIR2025/09566, internal review IR2025/11361]

DESNZ has a 'quasi-judicial' role as decision maker for these Nationally Significant Infrastructure Projects (NSIPs). However, Macquarie proposed to discuss a number of impacted named Island Green Power projects directly with DESNZ and NESO at a private meeting on 27 January 2025. [Sources: NESO FOI-25-240, 24–27 January 2025 correspondence; DESNZ Internal Review IR2026/03203, 24 April 2026]

On 7 April 2025, DESNZ removed the separate transmission/distribution solar allocations for 2031–35 and replaced them with combined regional totals. That did not increase the national solar target, but it materially changed which projects could compete for the available regional capacity – now favouring an increased number of transmission projects. [Sources: DESNZ, Michael Shanks MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025; 'Connections reform annex (updated)', April 2025]

The documents show a close sequence of private lobbying, project-specific discussion, reconsideration of NESO's 'independent' underlying analysis and a subsequent policy change which directly benefitted transmission developers. [Sources: NESO FOI-25-240; NESO FOI-25-317; NESO FOI-25-243 Additional Disclosure; DESNZ IR2026/03203; DESNZ solar capacity update letter, 7 April 2025]

Timeline of key events and disclosures

- 28 November 2024 — Macquarie contacts DESNZ following NESO's CP2030 advice, refers to its existing 'monthly catch up', raises significant concerns on behalf of its investment teams and

solar/storage portfolio companies, and asks for those concerns to be considered before DESNZ finalises its response and implementation of NESO's connection reform process begins. [Source: NESO, 'Request for Information', Ref. FOI-25-240, with disclosed Macquarie/IGP/DESNZ/NESO correspondence]

• 3 December 2024 — IGP, Enso Energy, Clearstone Energy and Innova write to the Secretary of State asking Government to reassess the allocation of solar between transmission and distribution 'or remove the distinction between the two altogether'. [Sources: 3 December 2024 IGP/Enso/Clearstone/Innova letter to the Secretary of State, disclosed under DESNZ EIR2025/09566 (internal review IR2025/11361); subsequently forwarded in NESO FOI-25-240 correspondence]

• 9–20 December 2024 — Macquarie forwards the developer letter and supporting material to DESNZ. It says 'The overall sentiment around the CP30 Action Plan grid reform changes remains negative at this point.' Macquarie tells DESNZ that its principal concern is the 'Lack of Flexibility Across Transmission and Distribution Targets for Solar' and warns that transmission projects may be cancelled or delayed. Macquarie are actively 'reviewing' the CP2030 Action Plan. DESNZ replies that it has been 'a pleasure working with you over the last year' and looks forward to 'building on this in 2025'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, with disclosed Macquarie/IGP/DESNZ/NESO correspondence]

• 8 January 2025 — Macquarie tells DESNZ that nine IGP projects totalling 5.2 GW are 'now at risk' under the CP2030 limits, asks to 'work collaboratively with the Government', and asks how Government will deal with regions where 'Transmission is oversubscribed and Distribution is undersubscribed'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, with disclosed Macquarie/IGP/DESNZ/NESO correspondence]

• 24–27 January 2025 — Macquarie and IGP prepare a project-specific presentation for DESNZ and NESO. The agenda proposes a 'Deep dive' into '6-7' 'case studies / assets of Island Green Power', detailed analysis of project impacts and risks, and 'Sense-checking of NESO's / DESNZ's thinking'. Macquarie identifies nine named projects across T4–T8 to be walked through, including East Pye Solar (Long Stratton PV and BESS). [Sources: NESO, 'Request for Information', Ref. FOI-25-240; DESNZ Internal Review IR2026/03203, 24 April 2026]

• 26 January: IGP asks NESO whether 'these projects' could be designated or otherwise protected and whether transmission technology caps could be increased. NESO replies that increasing the permitted capacities would require Government to reopen CP30 and states that NESO is 'not currently advising on the need for changes'. [FOI-25-243]

• 27 January 2025 — The IGP presentation, 'IGP Transmission Queue – Solar Only', uses projects across T4, T5, T6, T7 and T8 to illustrate 'Negative Changes because of CP2030'. The regional project detail is substantially redacted. [Sources: 'IGP Transmission Queue – Solar Only, Base Data V1', 27 January 2025, disclosed under FOI-25-240; DESNZ Internal Review IR2026/03203]

• February–March 2025 — FOI-25-317 shows wider transmission-solar lobbying of DESNZ, NESO and Ofgem, including requests to increase transmission capacity and concerns that projects could be removed from the queue. [Source: NESO, FOI-25-317 redacted disclosure ('Cat's Binder')]

• 7 April 2025 — DESNZ announces that the 2031–35 transmission and distribution solar allocations will be amalgamated after 'extensive' engagement with Ofgem, NESO and stakeholders. 'The misalignment has come about because the recent trend of increased solar project pipeline at transmission was not fully reflected in National Energy System Operator's (NESO's) 2024 Future Energy Scenarios, on which NESO's Clean Power 2030 advice to us was based.' The regional targets are changed to reflect the large number of speculative transmission solar projects in the existing pipeline, rather than reflecting NESO's original distribution/transition balance and regional energy balance analysis. Michael Shanks combines the Tx/Dx regional targets for 2031-35 as transmission developers had been requesting. [Sources: DESNZ, Michael

Shanks MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025; DESNZ, 'Connections reform annex (updated)', April 2025]

The original Clean Power 2030 approach

The purpose of the connections reforms was to reduce an oversized grid queue and move away from a system in which projects could retain connections simply because they had entered the queue early. The new approach was intended to give preference to projects which were sufficiently advanced and which were also aligned with strategic regional and technology requirements. A project could be technically viable and still fail to secure a Gate 2 position if the relevant regional technology capacity had already been filled. The original framework therefore did not assume that every advanced project should connect. On the contrary, excluding excess projects was part of the purpose of the reform.

Solar was also deliberately divided between transmission and distribution connection. For 2030 the national figures were 10.8 GW transmission and 36.2 GW distribution. The framework therefore envisaged a strongly distribution-led solar system. Distribution-connected solar can include commercial and industrial rooftops, warehouses, schools, car parks, brownfield sites and smaller ground-mounted schemes – these are decided by local planning. Transmission connection, by contrast, is commonly required for the very largest solar developments on thousands of acres of farmland. These (over 100MW) are categorised as Nationally Significant Infrastructure projects which are ultimately given development consent by DESNZ, not by local planning.

The IGP projects discussed with DESNZ and NESO illustrate the scale involved. Most were around 500 MW. Projects of that size can occupy thousands of acres and require extensive associated infrastructure, including substations, cable corridors, compounds, access roads, security fencing and, in some cases, wider reinforcement of the transmission network. The spatial consequences of delivering a large share of future solar through an increased number of 500 MW greenfield projects are plainly different from delivering more of it through dispersed rooftop, commercial, brownfield and smaller-scale generation.

There is also a consumer dimension. Transmission infrastructure is expensive, and congestion on the national network can generate significant constraint costs (which are paid to the scheme owner). Government's own Clean Power 2030 material recognises that strategic siting and network alignment are important to keeping system costs down. Connection level and location have system-cost consequences and were therefore an integral part of NESO's original strategic planning exercise.

Macquarie's engagement with DESNZ

The disclosed correspondence begins in late November 2024. On 28 November, Macquarie contacted DESNZ following publication of NESO's Clean Power 2030 advice. It referred to an existing 'monthly catch up' and said that its investment teams and solar and storage portfolio companies had significant concerns about the NESO connection reform proposals. Macquarie wanted those concerns considered before DESNZ finalised its response and before the new arrangements began to be implemented. It specifically asked to meet officials involved in the Government response to NESO. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

This is important because it shows that Macquarie was not commenting after policy had been settled. It was seeking to influence the Government response while the position was still under consideration. DESNZ subsequently facilitated engagement with senior officials in the 2030 Clean Power Unit. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

The 3 December 2024 letter

On 3 December 2024, Island Green Power, Enso Energy, Clearstone Energy and Innova wrote directly to Secretary of State Ed Miliband. Their concern was that NESO's regional and technology limits would result in a large number of transmission-connected solar projects failing to obtain Gate 2 connections under the new connections reform methodology (intended to remove excess projects from the transmission connection queue). [Source: 3 December 2024 letter from Island Green Power, Enso Energy, Clearstone Energy and Innova to the Secretary of State, disclosed under DESNZ EIR2025/09566 (internal review IR2025/11361) and forwarded in NESO FOI-25-240]

Their core argument was that the transmission queue was heavily oversubscribed while distribution capacity *might* be undersubscribed. [Source: 3 December 2024 letter from Island Green Power, Enso Energy, Clearstone Energy and Innova to the Secretary of State, disclosed under DESNZ EIR2025/09566; internal review IR2025/11361]

Their central request was explicit: 'We therefore urgently urge the government to reassess the allocation of solar across transmission and distribution, or remove the distinction between the two altogether.' This was not a minor request for clarification; it went to the architecture of the connections reform. [Source: 3 December 2024 letter from Island Green Power, Enso Energy, Clearstone Energy and Innova to the Secretary of State, disclosed under DESNZ EIR2025/09566; internal review IR2025/11361]

The developers were effectively saying that, where transmission solar exceeded the capacity set aside for it, those projects should be able to access capacity otherwise allocated to distribution-connected solar. Macquarie subsequently forwarded this letter and supporting material to DESNZ officials. [Sources: DESNZ EIR2025/09566 / IR2025/11361; NESO FOI-25-240]

Macquarie makes the same argument directly

On 20 December, Macquarie told DESNZ that its overall reaction to the CP2030 Action Plan 'remained negative'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence] It identified one of its principal concerns as the 'Lack of Flexibility Across Transmission and Distribution Targets for Solar'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence] Macquarie referred to the 10.8 GW transmission and 36.2 GW distribution allocations and argued that the transmission queue was oversubscribed while the distribution pipeline might be undersubscribed. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence] It warned that this could result in 'good quality Transmission-connected projects being cancelled or delayed'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

DESNZ's response also gives some context to the relationship. One official told Macquarie that it had been 'a pleasure working with you over the last year' and looked forward to 'building on this in 2025'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence] Taken with the reference to regular monthly catch-ups, this shows an established relationship rather than a single consultation contact. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

IGP's commercial exposure becomes explicit

On 8 January 2025, Macquarie gave DESNZ a much clearer picture of what was at stake for its own portfolio. [Source: NESO, 'Request for Information', Ref. FOI/25/240, disclosed correspondence] It

described IGP as its largest UK-based solar and BESS developer, with a portfolio exceeding 10 GW. It said that nine IGP projects totalling 5.2 GW were 'now at risk' because of the zonal and technology limits under CP2030. Macquarie then said that it wanted to 'work collaboratively with the Government' to understand whether there was a way to clarify the rules and enable further investment in those projects.

Among the questions it asked were how Government would shift allocation between distribution and transmission, and how it would deal with circumstances where 'Transmission is oversubscribed and Distribution is undersubscribed'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence] That question is particularly significant because the policy change announced three months later by Michael Shanks MP, Energy Minister, directly addressed the same issue.

FOI-25-243 demonstrates that IGP was also directly asking NESO about mechanisms by which affected projects could retain or obtain Gate 2 treatment. On 26 January 2025 IGP asked whether 'these projects' (names redacted) could be designated as aligned and whether technology caps could be increased in the transmission zones. NESO replied that increasing the permitted capacities would require Government to reopen the CP2030 Plan and stated that NESO was 'not currently advising on the need for changes'. The following day, Macquarie and IGP met NESO and DESNZ and identified individual affected projects across T4–T8, including East Pye Solar. The later Government decision to reopen the allocation methodology therefore followed directly after project-specific questions about protection and cap increases had been raised by IGP. [FOI-25-243; FOI-25-240]

The 27 January meeting

The 27 January 2025 meeting between DESNZ and Macquarie at the latter's London HQ, is the most important addition to the evidence. The original agenda proposed a 'Deep dive' into '6-7' 'case studies / assets of Island Green Power', together with 'more micro detail analysis of impact, planned projects and risks' and 'Sense-checking of NESO's / DESNZ's thinking'. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]. DESNZ asked Macquarie to confirm the projects in advance. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

Macquarie then said it had worked with IGP on a presentation and that a good way to conduct the discussion would be to go through specific projects in transmission zones T4–T8. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

It wrote:

'To do this we will walk through the following projects and the presentation attached live in the room.' [Source: NESO FOI-25-240, disclosed Macquarie email of 26 January 2025]

The projects listed were:

Region	Project	Capacity	Connection date
T4	Monk Fryston / Light Valley Solar	500 MW	Dec 2030
T4	Thornton	500 MW	Oct 2031
T5	Feckenham /Arrow Valley Solar	500 MW	Jul 2031
T5	Ironbridge	600 MW	Apr 2031
T5	Rugeley	600 MW	Aug 2031
T6	Grendon Solar & BESS / Green Hill	500 MW	Oct 2029
T6	The Droves	500 MW	Oct 2033

Region	Project	Capacity	Connection date
T7	Long Stratton PV & BESS Station / East Pye Solar	500 MW	Oct 2031
T8	Melksham / Lime Down	500 MW	Jul 2030

Source: NESO FOI/25/240, disclosed Macquarie email of 26 January 2025. The accompanying 27 January slide deck, 'IGP Transmission Queue – Solar Only, Base Data V1', is disclosed in redacted form under the same reference.

The significance of this list is that it shows the problem was not confined to East Anglia. Macquarie and IGP considered the original CP2030 methodology to threaten major parts of their transmission-solar portfolio across at least five regions. [Source: NESO, 'Request for Information', Ref. FOI/25/240, disclosed correspondence]

The associated slide deck was titled 'IGP Transmission Queue – Solar Only, Base Data V1 – 27 January 2025' and contained separate regional case-study material for T4, T5, T6, T7 and T8. [Source: 'IGP Transmission Queue – Solar Only, Base Data V1 – 27 January 2025', redacted slide deck disclosed under NESO FOI/25/240] One slide was headed 'IGP's Position – Negative Changes because of CP2030'. [Source: 'IGP Transmission Queue – Solar Only, Base Data V1 – 27 January 2025', redacted slide deck disclosed under NESO FOI-25-240]

The precise content of the regional project slides has been redacted. All nine IGP projects were identified in advance as projects to be walked through at the meeting, however the slides covered T7, T4, T5, T6, T8. [Sources: NESO FOI-25-240, 26 January 2025 project-list email; 'IGP Transmission Queue – Solar Only, Base Data V1 – 27 January 2025', redacted slide deck]

East Pye Solar as a case study

East Pye Solar shows particularly clearly why the original system was problematic for IGP. East Pye is a 500 MW transmission-connected project in T7/East Anglia, seeking an October 2031 connection. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence] IGP also has The Droves, another 500 MW scheme in the same T7 transmission region, seeking an October 2033 connection. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

Under the original December 2024 Connections Reform Annex, East Anglia had a total 2035 allocation of only 900 MW of transmission-connected solar. [Source: DESNZ, 'Clean Power 2030 Action Plan: Connections reform annex', December 2024, Table 2] East Pye Solar and The Droves alone therefore totalled 1,000 MW. In other words, those two IGP projects exceeded the entire original 2035 transmission-solar allocation for East Anglia before any competing developer's project was included. [Sources: NESO FOI-25-240; DESNZ, 'Clean Power 2030 Action Plan: Connections reform annex', December 2024, Table 2 (East Anglia: 900 MW transmission solar in 2035)]

That is important because it demonstrates the direct commercial interest IGP had in changing the transmission/distribution rules. [Sources: NESO FOI-25-240; DESNZ, 'Clean Power 2030 Action Plan: Connections reform annex', December 2024, Table 2]

Wider developer pressure

FOI-25-317 shows that other transmission-solar developers were also making detailed representations to DESNZ, NESO and Ofgem. [Source: NESO, FOI-25-317 redacted disclosure] The material records developers alleging significant discrepancies in the underlying transmission-solar data, seeking increases

in transmission capacity, and warning that otherwise advanced projects could be removed from the grid queue. [Source: NESO, FOI-25-317 redacted disclosure]

NESO referred internally to information obtained through previous developer engagement when considering updates to aspects of its solar data. [Source: NESO, FOI-25-317 redacted disclosure] NESO also acknowledged errors or possible miscategorisation in some of its underlying information. [Source: NESO, FOI-25-317 redacted disclosure]. This does not mean that the developers' evidence was improper. Developers may have been correct to identify errors. The important question is how commercially interested evidence was checked, independently verified and weighed within the final analysis.

DESNZ and NESO revisit the issue

By March 2025, DESNZ and NESO were carrying out further work on transmission and distribution solar. [Source: NESO, FOI-25-243 Additional Disclosure, 18 May 2026] FOI-25-243 records NESO supplying analysis to DESNZ and DESNZ thanking NESO for helping it reflect that analysis accurately in advice to ministers. [Source: NESO, FOI-25-243 Additional Disclosure, 18 May 2026] The relevant question is whether NESO's technical judgment remained independently reached and whether there is a clear evidential trail showing how developer representations were treated.

The 7 April change

On 7 April 2025, Minister Michael Shanks wrote to NESO announcing that the Connections Reform Annex would be amended. [Source: DESNZ, [redacted] MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025]

The reason given was a 'misalignment between solar capacity allocations and the solar pipeline for 2031 to 2035'. [Source: DESNZ, [redacted] MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025]

The Minister said that the recent increase in the transmission-solar pipeline had not been fully reflected in NESO's earlier Future Energy Scenarios analysis. [Source: DESNZ, [redacted] MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025]

He also stated:

'My department has engaged extensively with Ofgem, NESO, and stakeholders on this issue.' [Source: DESNZ, [redacted] MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025]

DESNZ decided that the existing flexibilities within the reform were not enough. It therefore amalgamated the separate transmission and distribution solar allocations for 2031–35. [Sources: DESNZ, [redacted] MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025; 'Connections reform annex (updated)', April 2025] The national solar total was not increased. But the competitive position of transmission projects changed materially.

Transmission schemes which had previously been confined by a separate regional transmission allocation could now compete against the combined regional solar total. For East Anglia, the original 2035 transmission-solar limit had been 900 MW. After the amendment, the relevant figure became a combined Tx+Dx regional solar allocation of 3.3 GW. [Sources: DESNZ, 'Clean Power 2030 Action Plan: Connections

reform annex', December 2024, Table 2; DESNZ, 'Connections reform annex (updated)', April 2025, Tables 2 and 4]

That removed the specific 900 MW transmission-only constraint which had made IGP's position so difficult. [Sources: NESO FOI/25/240; DESNZ solar capacity update letter, 7 April 2025; DESNZ 'Connections reform annex (updated)', April 2025]

Why this matters for the countryside

The April amendment was technically described as a change in allocation methodology, but the potential spatial consequences are significant. The original system placed a separate ceiling on very large transmission-connected projects within each region. Removing that ceiling means a greater proportion of the regional solar total can potentially be delivered through 500–600 MW transmission schemes.

That matters because the nine projects put forward by IGP demonstrate what transmission-scale solar means in practice: very large developments involving substantial areas of rural land. A system which allows several such projects to consume a large share of a region's solar capacity could result in more extensive greenfield development than a pathway which preserves a larger role for rooftop, commercial, brownfield and smaller distribution-connected solar.

The environmental question is therefore not simply whether the country needs solar. It is how much solar should be delivered through very large transmission-connected developments, where those projects should be located, and what the cumulative land-use consequences are.

Why this matters for consumers

The same issue has implications for system costs. Transmission solar is not inherently more expensive than distribution solar. Large projects can achieve economies of scale, while distribution networks also require reinforcement.

But generation location matters. If very large amounts of generation are connected in areas where the transmission system is already constrained, additional network reinforcement may be required and constraint costs can increase. Government itself has repeatedly emphasised that strategic spatial alignment is necessary to keep future system costs down. It has also said that renewable generation should connect at distribution level wherever possible for reasons of 'speed and efficiency'.

The consumer concern is therefore that weakening the original regional transmission limits may permit more generation to connect at transmission level than is systemically efficient, potentially increasing reinforcement, congestion and constraint costs which are ultimately borne by consumers. That is exactly why the original connections reform attempted to align generation by both region and connection type rather than simply allowing the queue to determine which projects proceeded.

NESO's independence

The chronology also raises an important governance issue. NESO is Government-owned, but it is intended to operate as an expert and operationally independent system operator and planner. [Source: DESNZ/NESO, 'National Energy System Operator Limited Framework Document', July 2026, §3.1 and related provisions] Its role includes providing Government with technical advice, analysis and information.

[Source: DESNZ/NESO, 'National Energy System Operator Limited Framework Document', July 2026, §3.1 and related provisions] Government is plainly entitled to set policy objectives, ask NESO questions, challenge assumptions and request further analysis. The concern is not that DESNZ and NESO communicated. The question is whether NESO continued to exercise independent professional judgment when the original regional and Tx/Dx methodology was reconsidered following substantial lobbying from transmission developers whose own projects were threatened by it. [Sources: NESO FOI-25-240; NESO FOI-25-317; NESO FOI-25-243 Additional Disclosure; 'National Energy System Operator Limited Framework Document', July 2026, §3]

That requires transparency about what developer evidence was supplied, what NESO accepted or rejected, what analysis changed, and whether the revised position was independently quality-assured.

Planning propriety

This transmission developer lobbying raises an additional issue because the Secretary of State for DESNZ will ultimately determine the project's DCO.

The sequence now established by the disclosures is straightforward.

Macquarie was the investor behind IGP. Macquarie was in recurring contact with DESNZ. It objected to the transmission/distribution restrictions, told DESNZ that 5.2 GW of IGP projects were at risk and asked Government to work collaboratively to resolve the problem. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]. DESNZ then asked Macquarie which projects it wanted to discuss. Macquarie and IGP expressly included specific projects to be walked through with DESNZ and NESO. [Source: NESO, 'Request for Information', Ref. FOI-25-240, disclosed correspondence]

Government subsequently removed the separate Tx/Dx solar allocations for 2031–35. [Sources: DESNZ, Michael Shanks MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025; 'Connections reform annex (updated)', April 2025]. The same Department's Secretary of State will later determine whether these same projects should receive development consent.

DESNZ says that it maintains separation between policy and investor-engagement teams and those advising ministers on individual planning decisions. [Source: DESNZ Internal Review IR2026/03203 (original case EIR2026/01321), 24 April 2026] That needs to be proved.

The concern is whether the combination of private project-specific engagement and the Department's later decision-making role gives rise to a legitimate appearance-of-bias or planning-propriety issue which requires transparent examination.

Transmission-scale NSIPs and compulsory acquisition

There is a further consequence of favouring very large transmission-connected solar projects which goes beyond landscape impact and network cost. Such projects are promoted through the Planning Act 2008 NSIP regime. If development consent is granted, a DCO can do considerably more than grant planning permission. It also confers powers to **compulsorily acquire the freehold of land and rights over land**, take temporary possession, impose or acquire new rights, override existing private rights and secure the land required to construct and operate the authorised development.

That gives the policy debate over transmission-scale solar an additional significance for rural landowners. A move towards a greater number of 500–600 MW solar NSIPs does not merely increase the amount of countryside potentially occupied by solar development. It potentially increases the amount of privately owned agricultural land brought within a statutory regime under which developers may seek compulsory acquisition powers.

Smaller solar projects proceeding through the ordinary local planning system do not acquire equivalent compulsory purchase powers simply by obtaining planning permission. The Planning Act NSIP regime, by contrast, permits the compulsory acquisition powers required for the project to be incorporated directly into the DCO determined by the relevant Secretary of State.

East Pye illustrates the issue particularly clearly. It is a privately promoted 500 MW solar project over a very large area of predominantly rural land. Its DCO application can seek statutory powers over land and rights required for the solar generating station and associated infrastructure. The ultimate decision on whether both the development and those compulsory acquisition powers are granted rests with the Secretary of State through the DCO process. NSIP applications are examined by the Planning Inspectorate, but the development-consent decision is made by the relevant Secretary of State.

That has to be considered alongside the FOI/EIR chronology. Macquarie and IGP were engaging privately with DESNZ about the connection rules affecting their own large transmission projects. IGP asked about mechanisms for protecting those projects and increasing transmission caps. Macquarie/IGP then placed individual schemes before DESNZ and NESO. DESNZ subsequently altered the Tx/Dx treatment in a way which improved the competitive position of transmission-scale projects. [FOI-25-243; FOI-25-240; DESNZ, Clean Power 2030 Solar Capacity Update Letter, 7 April 2025]

The public-interest concern is therefore wider than whether Macquarie's projects obtained favourable grid treatment. **Successful progression of these projects into the NSIP regime also gives their project companies access to a statutory route for seeking compulsory acquisition of the farmland and property rights needed to deliver them. These compulsory purchase powers which Macquarie is seeking are also granted by DESNZ.**

Key FOI/EIR references

• NESO FOI/25/240 — 'Request for Information' response and disclosed Macquarie/IGP/DESNZ/NESO correspondence; includes the 24–27 January 2025 meeting arrangements and the list of individual IGP projects to be walked through.

• 'IGP Transmission Queue – Solar Only, Base Data V1 – 27 January 2025' — redacted slide deck disclosed under FOI/25/240; contains T4, T5, T6, T7 and T8 project/region case-study slides and the heading 'IGP's Position – Negative Changes because of CP2030'.

• DESNZ EIR2025/09566; internal review IR2025/11361 — disclosure route for the 3 December 2024 letter from Island Green Power, Enso Energy, Clearstone Energy and Innova to the Secretary of State asking Government to reassess the Tx/Dx allocation or remove the distinction.

• NESO FOI-25-317 — redacted disclosure concerning wider developer challenges to transmission-solar data, requests for higher transmission capacity and NESO/DESNZ consideration of developer-supplied evidence.

• NESO FOI-25-243 — Additional Disclosure, 18 May 2026; DESNZ/NESO correspondence concerning transmission/distribution solar analysis and its use in advice to ministers.

• DESNZ EIR2026/01321 — response dated 25 February 2026 concerning Long Stratton PV & BESS / East Pye Solar and engagement with Macquarie/IGP; confirms quarterly IGP stakeholder meetings.

• DESNZ IR2026/03203 — 'Internal Review of response to Freedom of Information Request', 24 April 2026; acknowledges that the 27 January 2025 meeting had been missed from the original response, confirms the Macquarie/IGP presentation and explains the withholding of project material.

• DESNZ, 'Clean Power 2030 Action Plan: Connections reform annex', December 2024, Table 2 — original regional transmission-solar capacities, including 900 MW for East Anglia in 2035.

• DESNZ, Michael Shanks MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025 — records 'extensive' engagement with Ofgem, NESO and stakeholders and the decision to amalgamate Tx/Dx solar allocations for 2031–35.

• DESNZ, 'Clean Power 2030 Action Plan: A new era of clean electricity – Connections reform annex (updated)', April 2025 — implements the combined Tx/Dx regional allocations for 2031–35, including 3.3 GW for T7/East Anglia.

• DESNZ/NESO, 'National Energy System Operator Limited Framework Document', July 2026, §§3.1–3.4 — confirms NESO's operational independence, its role as an 'expert independent body', and the formal process for any shareholder direction or instruction.

Conclusion

The FOI and EIR material establishes a detailed chronology.

- The original Clean Power 2030 framework was designed to reduce an oversubscribed grid queue and align projects with regional and technology requirements.
- Solar was strongly weighted towards distribution connection.
- Large transmission-solar developers objected because many of their projects could lose Gate 2 status.
- On 3 December 2024, IGP and other developers asked Government to reconsider the division between transmission and distribution solar or remove the distinction altogether. [Source: 3 December 2024 letter from Island Green Power, Enso Energy, Clearstone Energy and Innova to the Secretary of State, disclosed under DESNZ EIR2025/09566; internal review IR2025/11361]
- Macquarie then pursued the same issue directly with DESNZ.
- By 8 January, it had identified nine IGP projects totalling 5.2 GW as being at risk. [Source: NESO, 'Request for Information', Ref. FOI/25/240, disclosed correspondence]
- 26 January: IGP asks NESO whether 'these projects' (redacted) could be designated or otherwise protected and whether transmission technology caps could be increased. NESO replies that increasing the permitted capacities would require Government to reopen CP30 and states that NESO is 'not currently advising on the need for changes'. [FOI-25-243]
- On 27 January, Macquarie and IGP proposed to walk DESNZ and NESO through nine named projects across T4, T5, T6, T7 and T8. The project list included East Pye Solar. [Source: NESO, 'Request for Information', Ref. FOI/25/240, disclosed correspondence]
- East Pye demonstrates the scale of IGP's commercial interest. Together with The Droves, IGP had 1 GW of proposed transmission-connected solar in East Anglia against an original 2035 regional transmission allocation of only 900 MW. [Sources: NESO FOI/25/240; DESNZ, 'Clean Power 2030 Action Plan: Connections reform annex', December 2024, Table 2 (East Anglia: 900 MW transmission solar in 2035)]

- Other transmission-solar developers were making similar representations. [Source: NESO, FOI-25-317 redacted disclosure]
- Further DESNZ/NESO analysis followed. [Source: NESO, FOI-25-243 Additional Disclosure, 18 May 2026]
- On 7 April, DESNZ said it had engaged 'extensively' with NESO, Ofgem and stakeholders and removed the separate transmission/distribution solar allocations for 2031–35. [Source: DESNZ, Michael Shanks MP, 'Clean Power 2030 Action Plan: solar capacity update – letter to NESO', 7 April 2025] That outcome closely corresponded with what transmission developers had been asking Government to do.

The available evidence establishes a sequence which deserves scrutiny: commercially interested developers privately advocated changes to rules threatening their own projects; individual projects were put before DESNZ and NESO; the analytical position was reconsidered; and Government subsequently changed the relevant methodology.

The public-interest implications extend beyond those individual projects. A shift towards more transmission-scale solar may have consequences for the amount of countryside required, the balance between large greenfield schemes and distributed solar, the need for transmission reinforcement and the network costs ultimately borne by consumers, and the potential loss of ownership of thousands of acres of UK farmland to international developers and investors such as Macquarie.

Annex A – Timeline

15 January 2026 – Your request

You asked us for the following information from NESO:

A. Core issue: Ofgem April 2025 'oversubscription' vs NESO 'alignment' claims for East Anglia

BEPS' position (already submitted in consultation materials) is that **Ofgem's April 2025 published analysis shows East Anglia already exceeded the relevant CP2035 (Tx+Dx) solar capacity by projects already consented or in planning**, meaning it is not apparent how a further NSIP-scale solar project could properly be assessed as 'aligned' with the regional target.

Accordingly, we request disclosure of the **recorded basis** on which NESO assessed 'alignment' in **East Anglia** at the point Gate 2 solar decisions were made.

B. Information requested (structured to avoid 'project-specific confidentiality' and focus on policy/decision records)

B1 — East Anglia 'alignment' assessment record (regional level, not project-by-project):

Please provide the documents/data tables (or extracts) showing, for the East Anglia region used by NESO in the Gate 2 assessment:

1. The **Tx+Dx CP2035 solar target figure** applied by NESO at Gate 2 assessment stage.
2. The **total solar capacity counted toward that target** (broken down by status categories used in your assessment, e.g., operational / under construction / consented / in planning / other categories used by NESO).
3. The **definition of 'in planning'/ 'committed' / 'pipeline'** used for the purposes of the Gate 2 alignment calculation, including what was included/excluded (and why).
4. Any **zone/system mapping inputs** used specifically to determine whether East Anglia was already at/over the CP2035 (Tx+Dx) solar target at the time of assessment.

(We are not asking you to identify individual projects in the queue; we are seeking the **regional totals and the method** by which 'oversubscription' or otherwise was determined.)

B2 — Reconciliation with Ofgem's April 2025 conclusion:

Please provide any NESO analysis, briefing, or internal note that **reconciles** (or addresses the discrepancy between) Ofgem's April 2025 conclusion that East Anglia was already over capacity and NESO's ability to treat further projects as 'aligned'.

B3 — Criteria for 'exceptional system need' / departures from oversubscription:

If NESO's methodology allows Gate 2 'alignment' for projects in regions already at/over CP2035 targets, please provide:

1. The criteria and thresholds for any such 'exceptional' treatment; and
2. The governance/approval route for applying that treatment (e.g., internal sign-off levels, decision logs).
3. Reasoning why NESO offered gate 2 grid connection for solar projects in East Anglia but only gate 1 to their associated BESS - therefore allowing no flexibility and increaing the liklihood of constraint in this already oversubscribed region.

B4 — Representations relevant to 'appearance of bias' and public confidence:

Given the public importance of confidence in an impartial connections regime, and your statement that the Tx+Dx update followed engagement with stakeholders,

we request copies of:

1. Any **representations, submissions, correspondence, meeting notes or minutes** between NESO and **DESNZ** relating to (a) the decision to merge Tx+Dx solar targets and/or (b) the rationale that East Anglia (and any other 'already met' regions) should still accommodate additional NSIP-scale solar projects; and
2. Any representations of the same kind from **Macquarie** and/or **Island Green Power** (including any group letters in which they participated) concerning **Gate 2 connections reform**, and specifically concerning solar capacity in regions where Ofgem's April 2025 analysis showed CP2035 targets already met — **especially East Anglia**.

This request is made because it is plainly in the public interest to understand whether, and how, stakeholder lobbying influenced (or appeared to influence) the revision of the regional methodology and the subsequent Gate 2 outcomes — a concern already set out in BEPS' procedural submissions on apparently compromised impartiality.

12 February 2026 – First part of our response

Your question at **A** is essentially the same point as B1.4 and B2, so please see responses below.

B1.1 - We used the solar capacity figure from Government's Clean Power 2030 Plan Connections Annex1. For East Anglia this is covered by zones D8 (distribution) and T6 and T7 (transmission) - noting that these are electrical zones and that the D8 zone covers significantly more than just the East Anglia region (e.g. it also covers Greater London, Essex and Kent) and there was no specific allocation to the East Anglia region of D8 for phase 1.

D8 – Phase 1 (needed by 2030): 8100MW

T7 – Phase 1 (needed by 2030): 100MW

T7 – Phase 2 (needed by 2035): 3300MW (noting that this also includes distribution connected projects within D8 that fall within the East Anglia region).

B1.2 - The figures for built/operational and Gate 2 solar are set out in our detailed results document3, specifically Table 2, Table 3, Table 6, Table 11, Table 12, Table 15 and Table 25, but are summarised below: **Zone**	**Built / operational solar**	**Phase 1 solar (of which 'protected')**	**Phase 2 solar**
D8 phase 1	2449.6MW	3084.6MW (2030.0MW)	See T7 phase 2
T7 phase 1	0MW	380.8MW (124.7MW)	See T7 phase 2
T7 phase 2	552.84MW5	See T7 phase 1	1860.8MW (47.0MW)

'Protected' means projects that met one or more of the 'protection criteria' set out in the connections methodologies – see pages 37 to 39 of the Gate 2 Criteria Methodology. We cannot provide any further breakdowns as the statuses which have already been presented and published were the only ones used in Gate 2 assessments, i.e. further recorded information is not held.

B1.3 - The Gate 2 calculations were determined in accordance with the connections methodologies published on NESO's website, as approved by the energy regulator (Ofgem).

B1.4 - The only input used to determine whether East Anglia was already at/over the CP2035 (Tx + Dx) solar target at time of assessment was the built/operational solar capacity for T7 at the time of the close of the Gate 2 submission window (26/08/25), i.e. 552.84MW as per the Table in response to B1.2. This meant that, in accordance with the connections methodologies (specifically section 5.4, page 28 of the Connections Network Design Methodology8), 2747.16MW9 of solar capacity was available to allocate in total to solar projects that met the Gate 2 criteria in zone T7 across phase 1 and phase 2.

B2 – As per the figures above in B1.4, zone T7 was not already over the solar capacity permitted for 2035. You will need to direct questions about Ofgem's figures to Ofgem. The Ofgem figures were estimates based on information collected before the G2TWQ evidence submission process, whereas NESO figures are determined directly from evidence submitted by customers and assessed by NESO.

B3 – As per the response to B2, zone T7 was not already over the solar capacity permitted for 2035. However, in general, and in accordance with the connections methodologies, the permitted capacity in a zone and/or at GB level for a technology can be exceeded by projects that meet the protection criteria (see response to B1.2).

As shown in the detailed results published by NESO, there was significant oversupply of batteries in zones D8 and T7, in phase 1 and phase 2, compared to the battery capacities for those zones set out in Government's CP30 Plan. This oversupply of batteries was because those batteries had all met the protection criteria referred to above.

B4 - We have completed searches for the correspondence which you requested. We need to complete final reviews of the correspondence returned in the searches to determine whether this information falls within the scope of your request, and if it does fall within the scope of your request, to determine whether any EIR exceptions apply, and to redact any personal data. Due to a high volume of requests at the current time we have unfortunately not managed to complete this process yet. We apologise for the delay and any inconvenience this may cause, but we are working to provide a response to this final part of your request in the next few working days.

9 March 2026 – Second and final part of our response

We can confirm that we hold recorded information in scope of your request.

We have undertaken a series of centralised searches of our email system for correspondence with the parties that you listed, and with a range of search terms appropriate to the information requested. In addition, we have searched the emails of key leaders and managers within NESO who were involved in communications with DESNZ, Macquarie and/or Island Green Power ("Island GP") on Gate 2 connections reform and specifically concerning solar capacity targets.

The following emails and documents fall within the scope of your request:

Item	Description	Disclosed Y/N	Applicable EIR exception(s) where info withheld/redacted – see explanations below
1.	Email thread between DESNZ and NESO in February/March 2025 relating to solar analysis on transmission: distribution splits, attaching documents with (1) NESO's responses to DESNZ questions on this subject and (2) NESO's solar capacity charts.	N	Some content not in scope of request EIR 12(5)(d)
2.	Email thread between NESO and Island GP in January 2025 in which NESO responds to questions from Island GP on the impact of zonal limits on projects.	Y	EIR 12 (5)(e) (project-specific info) EIR 13
3.	Email thread between NESO and DESNZ in February / March 2025, including forwarded emails between DESNZ and a developer of solar projects (not Island GP) in January / February 2025, with attached document (referred to in the emails as "letter to Minister Shanks") from the developer shared with DESNZ dated 20 February 2025, relating to the developer's analysis of transmission solar data.	Y	Some content not in scope of request (inc. developer's identity) EIR 12(5)(e) (info on developer's portfolio, comments on other developers' projects) EIR 13
4.	Email thread between NESO, DESNZ and Ofgem in February 2025 relating to solar capacities in the CP30 Action Plan.	N	EIR 12(5)(d)

5.	Email thread between NESO, DESNZ and Ofgem in February 2025 relating to stakeholder concerns around transmission: distribution splits.	N	EIR 12(5)(d)
6.	Email thread between NESO, DESNZ and Ofgem in March 2025 relating to an updated Impact assessment on amalgamation of zonal solar capacities.	N	EIR 12(5)(d)
7.	Extract relating to Tx and Dx capacity from a presentation document prepared by NESO for a Connections Reform Alignment session held on 13 February 2025 between NESO, DESNZ and Ofgem.	Y	
8.	Email thread between Macquarie and DESNZ between November 2024 and January 2025, forwarded by DESNZ to NESO in January 2025, relating to feedback on the CP30 Action Plan and arranging a meeting.	Y	EIR 12(5)(e) (project-specific info) EIR 13
9.	Extract from NESO's methodology change requirement tracker, referencing the potential change by Government of the Tx:Dx split for solar 2031-35 in an updated CP30 plan.	Y	
10.	Email thread between DESNZ and a developer of solar projects (not Island GP) between November 2024 and February 2025, forwarded by DESNZ to NESO in February 2025, relating to the developer's concerns on CP30 Action Plan caps for solar, with attached data tables produced by the developer of transmission solar caps for two T-zones.	Y	Some content not in scope of request (inc. developer's identity, and NESO spreadsheet and shapefiles referred to in emails) EIR 12(5)(e) (info re developer's portfolio) EIR 13

We would also draw your attention to the published letter from Minister Shanks to NESO's CEO dated 7 April 2025: Clean Power 2030 Action Plan: solar capacity update - letter to NESO, 7 April 2025. This sets out the reasons for the government's decision to amalgamate the Clean Power Action Plan solar distribution and transmission allocations for 2031-35. The letter explains that this measure was taken to address a misalignment between solar capacity allocations and the solar pipeline for 2031-35, that arose because a trend of increased solar project pipeline at transmission was not fully reflected in NESO's 2024 Future Energy Scenarios on which NESO's CP30 advice to DESNZ was based.

Removals/redactions of personal data

In the copy of those email threads and documents listed above that we are providing, all personal names, job titles and contact details have been redacted in accordance with the requirements of Regulation 13 of the EIR relating to protection of personal data.

Use of the exception at Regulation 12(5)(d)

Regulation 12(5)(d) allows a public authority to withhold information to the extent that its disclosure would adversely affect the confidentiality of proceedings where such confidentiality is provided by law. The ICO's guidance on this exception suggests that 'proceedings' can cover a range of activities but there must be a degree of formality. They include, but are not limited, to:

- formal meetings to consider matters that are within the authority's jurisdiction;
- situations where an authority is exercising its statutory decision-making powers; and
- legal proceedings.

We have determined that the following proceedings fall within Regulation 12(5)(d), as they each involve a means to formally consider an issue and reach a decision:

- NESO is the designated Independent System Operator and Planner as set out in Part 5 of the Energy Act 2023 and is licensed by Ofgem (Electricity licensing (from October 2025) - Publications - Ofgem Public Register). Our functions are set out in the Act and in the Framework document between the Department for Energy Security and Net Zero and National Energy System Operator. These functions include the provision of advice, analysis or information to a Minister of the Crown or Ofgem.
- NESO is also the code administrator for the Connections and Use of System Code (CUSC) which has undergone modification in relation to the connections reform process. CMP434 sets out the enduring process for applications and offers in Section 17 of CUSC and CMP435 sets out the "Gate 2 to Whole Queue" process for existing agreements in CUSC Section 18. The Code modification incorporates the updated connections methodology. There is a formal process for the consideration of code modifications which are approved by Ofgem.
- Additionally, we consider that the exercise of decision-making powers by the Department for Energy Security and Net Zero (DESNZ) in relation to updating the Clean Power 2030 Action Plan are 'proceedings' for the purpose of Regulation 12(5)(d).

The exception requires that there is a basis in law for the confidentiality of the proceedings. NESO is subject to Condition B7 (*Information ringfencing obligations*) of its electricity system operator licence, which requires NESO to identify confidential data and information that in its opinion should not be disclosed – this includes commercially sensitive information.

The exception only applies where the disclosure of information would adversely affect the

confidentiality of proceedings. We consider that disclosure of the withheld information would have a negative impact on the confidentiality of information shared. Although the EIR and FOIA do not automatically exempt information which is protectively marked, we note much of the withheld information was classified with protective markings.

In terms of the public interest, NESO recognises the presumption in favour of disclosure under the EIR and the general public interest in the accountability and transparency of public authorities. There is also a public interest in individuals being able to exercise their rights and take part in informed debate on matters of interest at local and national level.

We understand that local communities close to where projects are being considered or developed have a clear interest in understanding more about the decision-making processes that develop policy which impacts on their local area.

There is, on the other hand, a need for policy makers to take advice, and for public bodies to be able to conduct free and frank discussions about policies and policy changes and to test options and risks. Disclosure of the information would remove the protected space within which such discussions can take place, for example disclosure of discussions and analysis of risks may of it itself serve to make those risks more likely to materialise.

The licence condition at B7 covers market sensitive/commercial information and the energy sector is a highly competitive market which is currently engaging with the connections reform process. This is a 'live' process as offers are still being made and accepted. The connections reform process aims to drive economic growth and deliver a secure energy system across GB. The reforms are designed to clear the backlog of connections projects, unlock billions in investment, and pave the way to a sustainable energy future. It is not in the public interest to provide information which could disrupt the reform process and have a negative impact on the market.

The withheld information would not substantially aid public understanding of the policy decision/update and we believe that the public interest is satisfied by the information already published.

Use of the exception at Section 12(5)(e) of the EIR

We are refusing to provide the information referenced above under Regulation 12(5)(e) of the EIR. Information is covered by Regulation 12(5)(e) if:

- The information is commercial or industrial in nature;
- Confidentiality is provided by law;
- The confidentiality is protecting a legitimate economic interest;
- The confidentiality would be adversely affected by disclosure.

We consider that the requested information is commercial in nature as it relates to specific developer projects. We have consulted with the relevant developers to confirm that they information is commercial in nature.

In our opinion, the redacted information is confidential in law. NESO falls within the scope of the Utilities Act 2000 and Section 105 of that Act makes it a criminal offence to disclose information: a) obtained under the Utilities Act 2000 and any other key energy legislation such as the Gas Act 1986 and the Electricity Act 1989, subject to specific exceptions; and b) where the information relates to the affairs of any individual or any particular business during the lifetime of the individual or so long as the business continues to be carried on. There is also a common law duty of confidence with respect to the project and company specific information.

Our use of the exception at Section 12(5)(e) of the EIR is primarily in respect of the potential consequence to the developers' commercial interests which are covered by confidentiality obligations in the CUSC and under Section 105 of the Utilities Act. NESO has no specific consent from any of the developers referred to in the disclosed items to make public their commercial information.

Having consulted with the other parties, we are also satisfied that the confidentiality obligations are protecting legitimate economic and commercial interests and that the confidentiality would be adversely affected by disclosure under the EIR.

All exceptions in the EIR are subject to a public interest test.

NESO is mindful that the EIR requires us to apply a presumption in favour of disclosure when considering the public interest test. There is a general public interest in the accountability of NESO as a public corporation and in our transparency regarding our activities, including the connections reform process. We understand that local communities close to where projects are being considered or developed have a clear interest in understanding more about specific projects and the decision-making process and that there is a wider public interest in understanding how projects are developed and approved and how renewable energy infrastructure is used and sited.

Disclosure is likely to harm the relationship between NESO and connections customers and would reduce trust in NESO more widely in the energy sector. If suppliers of information are concerned about the disclosure of confidential information, such that they are unwilling to provide information in the future, this would have a detrimental effect on NESO's ability to carry out our role in delivering our licensed activities.

As the designated independent system operator and planner under the Energy Act 2023 NESO must remain independent, fair, and consumer focused. Disclosure could erode trust within the sector, hampering NESO's role and our ability to drive forward reforms and initiatives that would bring benefits to consumers and to the environment.

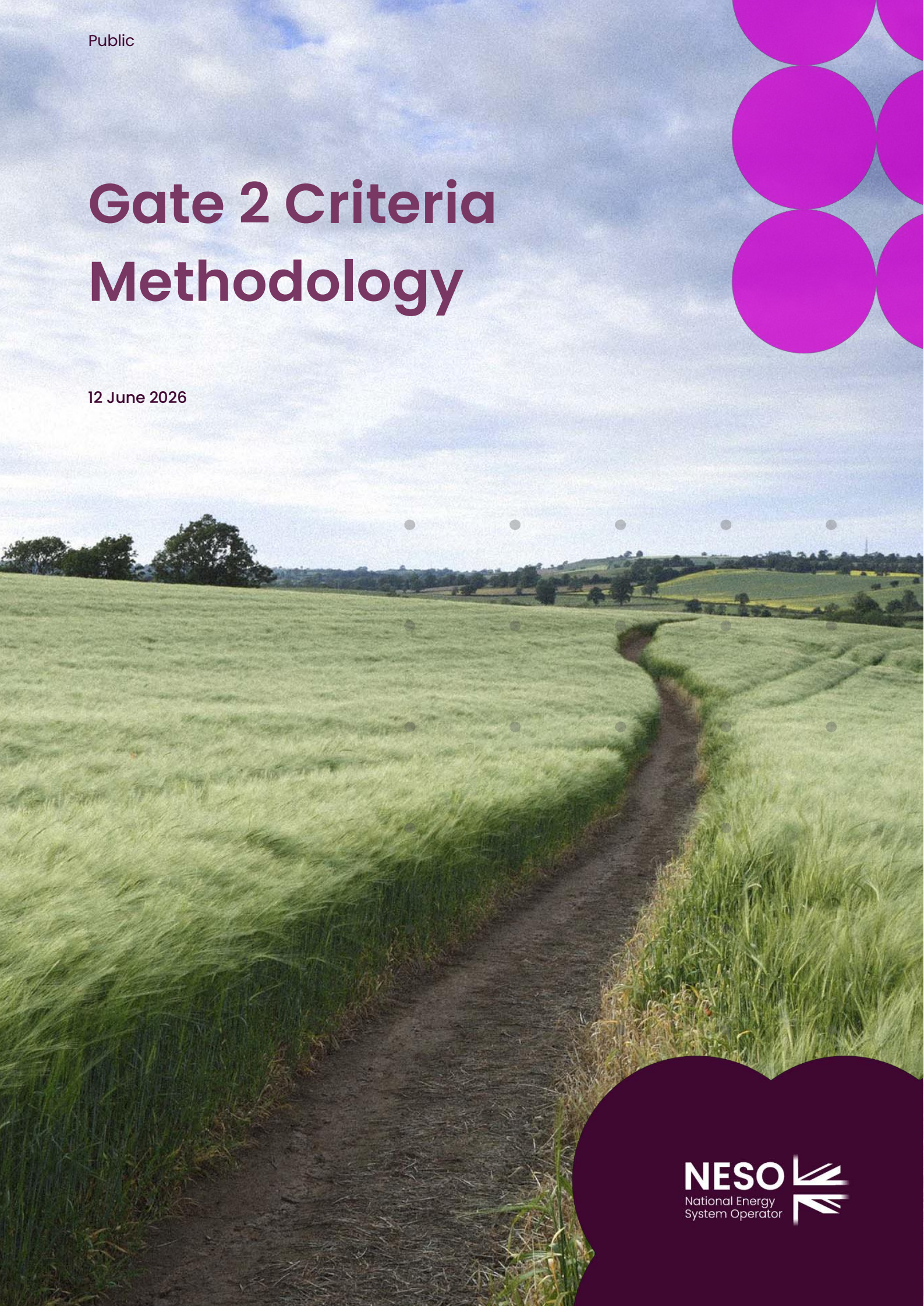
The confidentiality obligations in Section 105 of the Utilities Act make it an offence for us to disclose information provided to us by a developer and it is not in the public interest for public corporations to breach status. On the basis of this strong statutory obligation and the public interest arguments set out above, we believe that the balance of the public interest supports the use of the exception.

This concludes our response to your request.

Public

Gate 2 Criteria Methodology

12 June 2026



NESO
National Energy System Operator

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How to read this document

Welcome to our **Gate 2 Criteria Methodology** document. This document sets out the Gate 2 criteria for new applications and Gated Modification Applications that are required to meet the Gate 2 Criteria and the evidence requirements and assessment of this criteria.

This document will be reviewed and updated in line with the relevant ESO licence conditions.

This Methodology is applied under the reformed connection process introduced into CUSC as a result of CMP434 and needs to be read in the context of this process. CMP434 sets out the enduring process for applications and offers in Section 17 of the CUSC.

1. Purpose

This section introduces the purpose of the Gate 2 Criteria Methodology

The purpose of Gate 2 is to allocate confirmed connection dates, connection points and queue positions to projects that are viable and progressing and that are aligned with strategic energy plans.

This Gate 2 Criteria Methodology sets out the Gate 2 Criteria, which are in two parts:

- The Gate 2 "Readiness Criteria" – through a Readiness Declaration, a User will be required to provide evidence that their project is 'ready' by showing that it meets the "Gate 2 Readiness Criteria", which is set out within this Gate 2 Criteria Methodology, alongside detailing how the evidence required is submitted and verified; and
- The Gate 2 "Strategic Alignment Criteria" – a User will also need to meet one of these criteria, which are all set out within this Gate 2 Criteria Methodology, alongside the additional information or evidence a User needs to provide on their project to support the alignment assessment (against the relevant strategic alignment option/route).

For the avoidance of doubt, a User must (in respect of their project or the relevant stages of their project) meet both the Gate 2 Readiness Criteria and the Gate 2 Strategic Alignment Criteria to receive a Gate 2 Offer.

Please note that where we refer to Queue Management Milestones throughout this methodology, the requirements of that milestone (in accordance with the relevant published guidance) are also applicable to projects that do not have contracted milestones. For example, where 'M1' is required for the Development Consent Order Planning Route, a new applicant would need to provide evidence of having met 'M1' as part of the application process via the Readiness Declaration.

2. Scope

This section sets out the scope of the Gate 2 Criteria Methodology.

2.1 What is in scope of the Gate 2 Criteria Methodology and how does it fit in with Code, Licence and Guidance?

Methodology

- **Gate 2 Readiness Criteria**
  Land related or Planning related
- **Gate 2 Strategic Alignment Criteria**
  As per section 6 of this Gate 2 Criteria Methodology
- **Evidence requirements and evidence assessment process**

Code

- Explicit requirement to provide Original Red Line Boundary at submission of Gate 2 Application (unless Gate 2 Criteria Methodology states otherwise); and what it must contain at a high level (both CUSC 17.7) with further detail provided in Gate 2 Criteria Methodology
- Changes to Queue Management Milestones M1 and M3 (CUSC 16.3)
- New Queue Management exception (CUSC 16.5)
- Original Red Line Boundary compliance rule (CUSC 16.4.9) and impact of being outside compliance (CUSC Schedule 2, Exhibits 3 and 3A)
- Requirement to carry out 100% duplication checks and use reasonable endeavours to check 100% of Gate 2 Readiness Criteria evidence provided (CUSC 17.10)

Gate 2

Licence

- Requirement to have a Gate 2 Criteria Methodology, consult on it, keep "live" and be approved by Ofgem

Guidance

- Queue Management – additional explanation on the new Queue Management exception set out in Code and how ongoing land and planning compliance works in practice
- Letter of Authority / Letter of Acknowledgement – inclusion of equivalent land density test for Offshore and Energy Density values (and/or equivalents) for Offshore projects (including Interconnectors and or Offshore Hybrid Assets (OHAs) onshore converter stations)

2.2 Who does the Gate 2 Criteria Methodology apply to?

- Transmission connected (Generation[1] and Demand)
- Interconnectors, Offshore Hybrid Assets and Non-GB Projects[2]
- Large Embedded Generation (apply to NESO)[3]
- Small and Medium Embedded Generation (via DNO/Transmission Connected iDNOs, who apply on their behalf to NESO)[3]. This includes:
    - Relevant Embedded Small Power Stations;
    - Relevant Embedded Medium Power Stations;
    - Embedded Small Power Stations with a Bilateral Embedded Generation Agreement[4]; and
    - Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement[4].

Supporting Notes

[1] For the avoidance of doubt this includes storage.

[2] Generation located outside of Great Britain and the UK's Exclusive Economic Zone, but which is directly connected to the GB Transmission System or Distribution System and is not connected to another market.

[3] Embedded Generators will have to meet DNO/Transmission Connected iDNO requirements in addition to the Gate 2 Criteria outlined in this methodology.

[4] Embedded Small Power Stations and Embedded Medium Power Stations wanting to request a BEGA will still be required to submit a BEGA application to NESO in addition to DNO/Transmission Connected iDNOs applying on their behalf to NESO.

3. Gate 2 Criteria Summary

This section sets out a summary of the Gate 2 Criteria

3.1 Summary of Gate 2 Criteria

Project stage must meet the Gate 2 Readiness Criteria (See Sections 4 and 5 for more detail) - either the requirements of Section 4 (Land) or Section 5 (Planning)

LAND (See Section 4)

- Meet Minimum acreage requirements (or Offshore equivalent as set out in Section 4.1a); and
- Provision of Original Red Line Boundary for site on which project is located; and
- Secured Land Rights

or

PLANNING (See Section 5)

- Submission of (and validation of) application for planning consent for projects following the Development Consent Order (DCO) process i.e. meeting the requirements of Queue Management Milestone M1. Note that we would expect the majority of projects to evidence meeting Gate 2 Readiness Criteria through the land route as per Section 4; however, this planning alternative allows projects that follow the DCO process (including to be granted Compulsory Purchase Order powers) an alternative route to meeting the Gate 2 Readiness Criteria; and
- If following the Planning route, meeting Minimum acreage requirements and the provision of the Original Red Line Boundary for the site on which project is located must both be done as part of evidence of meeting Queue Management Milestone M2

And Project technology stage must then meet one of the Gate 2 Strategic Alignment Criteria (See Section 6 for more detail)

a) Eligible for relevant 'protections' as set out in Section 6.2; or
b) Aligned to the capacities within the CP30 Action Plan as described in the Connections Network Design Methodology; or
c) Designated as described in the Project Designation Methodology; or
d) A project not within scope of the CP30 Action Plan and of a technology type listed in the table in Section 6.3

There will also be ongoing compliance requirements (See Section 7 for more detail)

Once a project technology stage has met the Gate 2 Criteria and the User has signed the Gate 2 Offer, there will be ongoing compliance requirements regarding the land and planning. These obligations are set out in CUSC Section 16 and expanded on further in the Queue Management Guidance. However, Embedded Power Stations' Queue Management Milestones and ongoing land compliance requirements will continue to be managed by DNOs or Transmission Connected iDNOs.

If following the Planning route to meet the Gate 2 Readiness Criteria, the ongoing land compliance requirements will apply from when the User has met Queue Management Milestone M2.

4. Gate 2 Readiness Criteria – Land

This section sets out the Gate 2 Readiness Criteria if seeking to meet Gate 2 Readiness Criteria via evidence of secured land rights

4.1 Gate 2 Readiness Criteria – Secured Land Rights

In order to demonstrate that a User has secured the rights to lease or own the land (or already leases or owns the land) for the site on which their project is planned to be located, they must meet each of the following three criteria: (a)-(c)

a) Meet Minimum acreage requirements	b) Provision of Original Red Line Boundary	c) Secured Land Rights
This relates to 100% of the land which is required for their project to meet the Gate 2 criteria. This 100% requirement will be calculated using the Energy Density Table contained in the NESO guidance document, unless set out otherwise in the Gate 2 Criteria Methodology. Offshore specific arrangements will also be set out within such guidance.	As set out in CUSC Section 17, the User would also need to provide the Original Red Line Boundary for their project site showing the land they have secured.	Either: **Option** – any Option agreement must have a minimum 3-year period (unless discretion applied via this Gate 2 Criteria Methodology) from the date the Option is signed (and not the date the Gate 2 application is submitted). There will be an ongoing requirement for the User to keep the land under option by seeking further agreements (or keeping or extending the same agreement already in place) with the landowner until the connection date. The Option Agreement must be accompanied by (or contain within) a Form of Lease (also known as an Option to Lease) or a Purchase Agreement/Transfer (also known as an Option to Purchase). The form of lease must reflect the typical minimum operational timelines for that type of project and this will be a minimum of 20 years from the date of exercise of the Option unless the User can demonstrate, to the reasonable satisfaction of NESO or the DNO/Transmission Connected iDNO, that the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects. This minimum 20-year requirement is not applicable for a Purchase Agreement/Transfer; or **Evidence of existing ownership** via provision of the Official Copy of The Register of Title (known as Title Sheet in Scotland) and Title Plan where land registered at Land Registry, or via certification of title signed by the User's solicitor (inclusive of Title Plan) where land not registered at Land Registry at the time of submission of the Gate 2 evidence; or **Existing land lease** with a remaining term of minimum of 20 years from the submission of the Gate 2 evidence, unless the User can demonstrate to the reasonable satisfaction of NESO or the DNO/Transmission Connected iDNO, that the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects.

4.1a Gate 2 Readiness Criteria – Meet Minimum acreage requirements

Relates to 100% of the land which is required for their project to meet the Gate 2 criteria. This 100% requirement will be calculated using the Energy Density Table contained in the NESO guidance document unless set out otherwise in this section of the Gate 2 Criteria Methodology. Offshore specific arrangements will also be set out within such guidance.

Where a User has multiple project stages seeking to meet the Gate 2 criteria, the User will need to provide the acreage value for that specific project stage rather than a cumulative value for the whole Project.

Where there is more than one technology within a Project stage the User will need to meet the total minimum acreage requirements for each of the technologies in that stage unless otherwise agreed by NESO or the DNO/Transmission Connected iDNO under the process set out in the NESO guidance document.

Key Notes:

As set out in the NESO guidance document, the Energy Land Density table will be reviewed annually by the NESO to take into account any updates or changes to technology types. The NESO will engage with industry prior to publishing any amendments to the table.

Energy Density values (and/or equivalents) for Offshore projects (including Interconnectors and/or Offshore Hybrid Assets (OHAs) will be included in the NESO guidance document. Please note that for Interconnectors, OHAs and Non-GB projects, the minimum acreage requirement will be in relation to whether the applied for capacity (in respect of Gate 2) and the onshore converter station area are consistent with the energy density table information.

Where the Original Red Line Boundary provided (under 4.1b of this Gate 2 Criteria Methodology) has an acre per MW which is less than that in the Energy Land Density table, Users will need to justify why a reduced minimum acreage is appropriate for their Project Site for that stage. Users should proactively explain this on their Readiness Declaration and queries will be raised by the NESO or Transmission Connected iDNO/DNO with the User in an attempt to fully understand the context of why this is relevant for that project stage. However, in the event that NESO or Transmission Connected iDNO/DNO is not satisfied that the total land acreage provided meets the de minimis level, the minimum acreage requirement will not have been met.

Emerging technology types that are not represented in the Energy Land Density table will be treated on a case-by-case basis.

4.1a Gate 2 Readiness Criteria – Meet Minimum energy density requirements calculation (Offshore process variation)

This variation applies in the case of a project securing an award for seabed lease from The Crown Estate (TCE) and/or Crown Estate Scotland (CES) in relation to energy generating projects in GB waters, such as wind, wave and tidal, and so not including interconnectors, OHAs and Non-GB Projects.

For such offshore projects (excluding Interconnectors, OHAs and Non-GB Projects), if the capacity that the User has requested in their Gate 2 Application equates to what has been awarded by TCE or CES, this will be sufficient in lieu of reference to the energy density table.

In the event this is not the case, the Offshore specific energy density table as set out in the NESO guidance document will be used to determine Gate 2 Criteria readiness in relation to the minimum seabed equivalent requirement. It is possible that only a portion of the project meets the Gate 2 Readiness Criteria, and the User will need to take necessary steps (e.g. staging Transmission Entry Capacity or reducing Transmission Entry Capacity) to match the energy density table in order to meet the minimum acreage equivalent requirement.

4.1b Gate 2 Readiness Criteria – Provision of Original Red Line Boundary

As set out in CUSC Section 17, the User would also need to provide the Original Red Line Boundary for their project site per stage showing the land they have secured.

The project site is the main generation/demand site and excludes the cable routes or access roads or land needed for the network substation or land required for non-energy purposes (e.g. agricultural such as grazing sheep at a wind farm or solar installation or leisure usage such as mountain-bike tracks at a wind farm). Indicative areas for substations do not need to be depicted within the Original Red Line Boundary.

For the purpose of readiness, projects with multiple stages must provide a separate Original Red Line Boundary for each stage. However, it is also acceptable to use the same Original Red Line Boundary for each stage.

The criteria a User must meet here are as follows:

Show the Original Red Line Boundary of the site on which the project is located

- Original Red Line Boundary should be clearly marked;
- Where the Original Red Line Boundary covers multiple land parcels, it is recommended to include this on the Original Red Line Boundary (however this is not mandatory);
- Indicate the scale and orientation used;
- Explain any symbols, colours and abbreviations used;
- This does not need to show the project's cable route, or the land needed for a network substation or land used for non-energy purposes (e.g. agricultural such as grazing sheep at a wind farm or solar installation or leisure usage such as mountain-bike tracks at a wind farm);
- Where there is more than one technology within the Project Site, the User will not be required to provide an Original Red Line Boundary for each technology (apart from where a project stage has both an onshore and offshore component and the User will then need to separately show the Original Red Line Boundary and the Grid Coordinates for the onshore and offshore component). Note that the User will still need to provide the installed capacity for each technology and the Original Red Line Boundary will need to be large enough to encompass all technologies; and
- In addition, it is recommended to supply a GeoJSON file of the Original Red Line Boundary – however this is not mandatory.

Original Red Line Boundary must also show the following:

- **Location**
  - Site address including postcode (if available); and
  - Grid Coordinates (Longitude and Latitude in WGS84 decimal (and not degrees, minutes, seconds) format to 4 decimal places of Northerly, Easterly, Southerly and Westerly extreme coordinates of project site).
    - For the purpose of readiness, projects with multiple stages must provide separate grid coordinates for each stage. However, it is also acceptable to use the same grid coordinates for each stage.
- **Installed Capacity (expressed in whole MW or to one decimal place) for each technology per project stage**
  - Definition in CUSC Section 11; and
  - As per CUSC Section 17.7, the sum of the Installed Capacity provided within a Gate 2 Application and the capacity of any existing User's Equipment or Developer's Equipment at the same site (if any), must be equal to or greater than the total Transmission Entry Capacity or Developer Capacity or directly connected Demand MWs.
  - For Transmission Connected Demand Sites where the capacity is listed in MVA, Users should apply a unity power factor to convert to MW i.e. 100MVA would be 100MW.
  - Where a User has multiple project stages seeking to meet the Gate 2 criteria, the User will need to provide the Installed Capacity for that specific project stage rather than a cumulative value for the Project.
- **Total acreage secured within the Original Red Line Boundary in respect of the Project Site per project stage**

Ongoing compliance requirements regarding the Original Red Line Boundary are set out in CUSC Section 16 and expanded on further in the Queue Management Guidance. Note that Embedded Power Stations' ongoing land compliance requirements will continue to be managed by DNOs or Transmission Connected iDNOs.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Overview

User must provide evidence of secured land rights under one of the following methods:

Option Agreement - An option agreement is where the User enters into an agreement with a landowner for the right to buy or lease their land. The User has the option to purchase or lease the land (within a period defined in the agreement) but is not under obligation to do so. The User will usually pay a sum of money to the landowner for the right to exercise the option, known as an option fee. The User will usually be required to serve the landowner with an 'Option Notice' and pay a deposit at the point they wish to exercise the option.

Conditional agreements for leases, sale contracts, and missives will be treated similarly to Option Agreements and will be accepted provided the conditions are acceptable. A Promotion Agreement is only acceptable evidence if it meets the minimum requirements for evidencing relevant land rights as set out within this Gate 2 Criteria Methodology.

Although the length of Option agreements can vary, the Option agreement must be "live" and have a minimum 3-year period (unless discretion applied via this Gate 2 Criteria Methodology) from the date the Option is signed (not the date the Gate 2 application is submitted).

There will be an ongoing requirement for the User to keep the land under option by seeking further agreements (or keeping or extending the same agreement already in place) with the landowner until the connection date.

The Option Agreement must be accompanied by (or contain within):

- a Form of Lease (also known as an Option to Lease); or
- a Purchase Agreement/Transfer (also known as an Option to Purchase).

The Form of lease, must reflect the typical minimum operational timelines for that type of project and this will be a minimum 20 years from the date of exercise of the option unless the User can demonstrate, to the reasonable satisfaction of NESO or the DNO/Transmission Connected iDNO, that the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects. This minimum 20-year requirement is not applicable for a Purchase Agreement/Transfer (also known as an Option to Purchase); or

Evidence of existing ownership must be either:

- via provision of the Official Copy of The Register of Title (known as Title Sheet in Scotland) and Title Plan where land registered at Land Registry; or
- via certification of title signed by the User's solicitor where land not registered at Land Registry at the time of submission of the Gate 2 evidence; or

Existing land lease with a remaining term of minimum of 20 years from the submission of the Gate 2 evidence unless the User can demonstrate, to the reasonable satisfaction of NESO or the DNO/Transmission Connected iDNO, that the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Things to note when providing evidence

The secured land rights (apart from when related to Evidence of Existing Ownership) must be signed by both the User/Applicant and the landowner (or their authorised agent).

If the documentation is not signed by both parties, we require the counterpart signed by the landowner(s).

The User should also be the party who has entered into the secured land rights.

Where the User is not the party who has entered into the secured land rights, the User must provide a signed letter from the entity who holds the land rights stating that User has the rights to use the land.

However, we note in practice there are scenarios where connection agreements are held in one company and the land rights are put in the names of the specific SPV with both these companies under the direct control of the same parent company. In these cases, we will allow this requirement to be met via a signed letter from the director or authorised person, to explain the fact that the land rights company and applicant are under control of the same group company and that the land rights and connection offer will be within the same SPV at construction.

The Secured Land Rights must not include landowner unilateral termination provisions.

Noting there will always be standard termination provisions, in principle an acceptable termination provision is one that is in the User's control. Conversely, an unacceptable termination provision is one that is fully in the landowner's control.

Note this is not applicable if following the "Evidence of existing ownership" route to readiness.

The User must provide evidence of secured land rights for all their Project Site stage(s) (as identified by their Original Red Line Boundary for each stage).

We strongly recommend that Users provide a composite plan as part of their Readiness Declaration showing the secured land rights boundaries to ensure comparison between this and each Original Red Line Boundary. Where this is not provided, and we cannot verify that there are secured land rights in place for each Original Red Line Boundary, we will request this to be provided as part of the detailed checks process.

Evidence of Secured Land Rights is required per land parcel within the Original Red Line Boundary for each stage.

There is no formal definition of what a land parcel is. However, in principle every title/existing lease/option agreement is a different parcel, irrespective of whether they are contiguous. Therefore, separate fields could be the same "parcel" if on the same title/existing lease/option agreement.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Commercial Sensitivities

We note that land status information would need to be heavily caveated such that the User can withhold any information it deems commercially sensitive.

Therefore, redacted land agreements are allowed to be provided if only the financial/commercial information is redacted. We will ensure these are stored in a secure location with no ability for information to be accessible by anyone unless they have the authority to do so and must not be made public.

However, we will need to be satisfied that the land agreements provided meet the Gate 2 Readiness Criteria for Land (which in the case of the Option Agreement could be via one of the listed exceptions, set out in this Gate 2 Criteria Methodology). We will contact Users for further explanation as part of detailed checks if more than financial/commercial information has been redacted, which we reasonably believe could impact whether the Gate 2 Readiness Criteria have been met.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Option Agreement

Option Agreement - must be "live" and have a minimum 3-year period (unless discretion applied via this Gate 2 Criteria Methodology) from the date the Option is signed (not the date the Gate 2 application is submitted).

There will be an ongoing requirement for the User to keep the land under option by seeking further agreements (or keeping or extending the same agreement already in place) with the landowner until the connection date.

What do we mean by a 3-year minimum option length?

- The Option agreement must have a minimum 3-year period (unless discretion applied via this Gate 2 Criteria Methodology) from the date the Option is signed (not the date the Gate 2 application is submitted). Note that the Option must continue to have at least a 3-year minimum period unless it meets one of the exceptions in this section of the Gate 2 Criteria Methodology.
- Noting that options are structured differently, and we do not wish to unnecessarily restrict a commercial negotiation, how the 3-year minimum option length is structured is in the User's control, but it needs to ensure e.g. that the landlord has no unilateral termination provision (except in the event of default by the tenant). Therefore, it would be acceptable for an option that includes an initial term and an allowed extension (that in total constitutes >= 3 years) that can be granted on payment of an extension fee by the User to the landlord e.g. a right to extend by a further period if a planning application has been submitted. We note that some Option Agreements can be automatically extended without the need for a newly signed Option Agreement. However, where this means the Option Agreement would appear to have expired, we require signed evidence that the extension has been activated. This evidence may be practically different in each case but could include confirmation from the landowners and/or the User's solicitor that the extension has been activated.
- The detailed checks to be undertaken are set out in Section 8 of this Gate 2 Criteria Methodology.
- A User having an exclusivity agreement is not sufficient evidence of such land rights.
- Additionally, Heads of Terms, which is a preliminary agreement that outlines the key terms and conditions and timescales for the User to secure an Option from the landowner to purchase or lease the land for the purposes of the proposed connection, is not sufficient evidence of such land rights.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Option Agreement Exceptions to Minimum Length period

Exceptions to 3-year minimum option length:

- Evidence from the User that having to have and/or maintain a 3-year validity detrimentally impacts development of the project. We will consider on a case-by-case basis, but the only exceptions we currently envisage to be considered in this regard are:
    - a test and demonstration project which would be around for a period less than 3 years; or
    - where the project is reasonably able to demonstrate that it does not need a further 3 years before it will enter into the lease (or purchase) e.g. the option is entered into just prior to construction, so although the project has or is seeking a connection date greater than 3 years away, it has less than 3 years left on its option, because there is less than 3 years before the project will expect to enter into the lease (or purchase).

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Option Agreement Exceptions to providing secured land rights (Compulsory Purchase Order)

Option Agreement Other Exception: Evidence of Compulsory Purchase Order Powers granted

Although, in most circumstances, the User should have secured land rights over all of their proposed project site before they make a Gate 2 Application, there are circumstances where a User may be unable to obtain the necessary land rights as they can only acquire all the land required, or part of the land required, through the granting of Compulsory Purchase Order (CPO) powers. This exception is only allowable under the following circumstances:

- At Gate 2 Application, the User must provide evidence of the granted CPO powers for all the land (or the relevant part) which may be acquired through those granted CPO Powers.
- At Gate 2 Application, the User must meet all the requirements under "Gate 2 Readiness Criteria – Land" for the land that is not associated with the granted CPO Powers. Note that the Installed Capacity provided under section 4.1b should also include the land associated with the granted CPO Powers.
- At Gate 2 Application, the User must indicate on the Original Red Line Boundary as per section 4.1b (or provide a separate draft Original Red Line Boundary) the red line boundary for the land associated with the granted CPO Powers and also confirm the minimum acreage for this land, as per section 4.1a. Ongoing Original Red Line Boundary Compliance will be based on this information.
- At Queue Management Milestone M3 (at transmission or distribution), the User must provide evidence of secured land rights for the land (including any acquired through CPO powers) and re-confirm the Original Red Line Boundary and minimum acreage.

In Section 5 of this Gate 2 Criteria Methodology, we have included a planning alternative which allows projects that follow the DCO process (including to be granted Compulsory Purchase Order powers) an alternative route to meeting the Gate 2 Readiness Criteria via the submission of (and validation of) their application for planning consent (Queue Management Milestone M1 - at transmission or distribution). Where a User evidences to NESO or the DNO/Transmission Connected iDNO, ahead of the Gated Application Window opening, that they need to follow an alternative planning process (other than the DCO route) in order to be granted Compulsory Purchase Order powers to secure relevant land rights, NESO may apply discretion on a case-by case-basis in respect of this aspect of the Gate 2 Readiness Criteria (in line with the above).

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Option Agreement Exceptions to providing secured land rights (Probate)

Option Agreement Other Exception: User may be unable to complete the land option due to the ownership of a parcel of land being in probate following a death.

Although, in most circumstances, we believe that the User should have secured land rights over all their proposed project site before they make a Gate 2 Application, there is a circumstance where a User may be unable to complete the land option due to the ownership of a parcel of land being in probate following a death.

This exception will be allowable (even where all the land the User needs for the project is in Probate) under the following circumstances:

- At Gate 2 Application, the User must meet all the requirements under "Gate 2 Readiness Criteria – Land" for the land not in Probate. Note that the Installed Capacity provided should also include the land under probate.
- At Gate 2 Application, the User must meet all the requirements under "Gate 2 Readiness Criteria – Land" for the land that is not being acquired through Probate. Note that the Installed Capacity provided under section 4.1b should also include the land to be acquired through Probate.
- At Gate 2 Application, the User must indicate on the Original Red Line Boundary as per section 4.1b (or provide a separate draft Original Red Line Boundary) the red line boundary for the land being acquired through Probate and also confirm the minimum acreage for this land as per section 4.1a. Ongoing Original Red Line Boundary Compliance will be based on this information.
- At Queue Management Milestone M3 (at transmission or distribution), the User must provide evidence of secured land rights for the land that was in Probate and re-confirm the Original Red Line Boundary and minimum acreage.

4.1c Gate 2 Readiness Criteria - Secured Land Rights: Option Agreement (Form of Lease or Purchase Agreement/Transfer)

The Option Agreement must be accompanied by (or contain within):

- **a Form of Lease (also known as an Option to Lease) or**
- **a Purchase Agreement/Transfer (also known as an Option to Purchase).**

The Form of Lease, must reflect the typical minimum operational timelines for that type of project and this will be a minimum 20 years from the date of exercise of the option unless the User can demonstrate, to the reasonable satisfaction of NESO or the DNO/Transmission Connected iDNO, that the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects. This minimum 20-year requirement is not applicable for a Purchase Agreement/Transfer (also known as an Option to Purchase).

As the contracted connection date will not necessarily be known at the time that the User is negotiating the Option Agreement with the landowner, the minimum 20 years will apply from the date of exercise of the option.

If the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects, then Users should explain this within their Readiness Declaration and NESO or the DNO/Transmission Connected iDNO will allow an exception here if the operational life of the project is evidenced to be less than 20 years.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Existing Ownership

Evidence of existing ownership must be either:

- **via provision of the Official Copy of The Register of Title (known as Title Sheet in Scotland) and Title Plan where land registered at Land Registry; or**
- **via the certification of title signed by the User's solicitor where land not registered at Land Registry) at the time of submission of the Gate 2 evidence.**

Where the User already owns the land at which the project is to be located, the User must either:

- Provide the Official Copy of The Register of Title (known as Title Sheet in Scotland) and Title Plan where registered at Land Registry; or
- Provide certification of title signed by the User's solicitor where land not registered at Land Registry. This will need to confirm that the land interest is owned / vested in the User.

4.1c Gate 2 Readiness Criteria – Secured Land Rights: Existing Land Lease

Evidence of existing land lease with a remaining term of minimum of 20 years from the submission of the Gate 2 evidence unless the User can demonstrate, to the reasonable satisfaction of NESO or the DNO/Transmission Connected iDNO, that the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects.

As the contracted connection will not necessarily be known at the time that this evidence is submitted, the minimum 20 years will be calculated from the date of submission of the Gate 2 evidence.

If the expected operational life of the project is less than 20 years e.g. in relation to test and demonstration projects, then Users should explain this within their Readiness Declaration and NESO or the DNO/Transmission Connected iDNO will allow an exception here if the operational life of the project is evidenced to be less than 20 years.

4.1c Gate 2 Readiness Criteria – Secured Land Rights (Differences of Approach)

In terms of securing land, there are minor differences of approach for Non-GB Projects, Offshore Hybrid Assets (OHAs) and Interconnectors and Innovation and Targeted Oil & Gas (INTOG) projects to reflect the practicalities of how they would meet the Gate 2 Readiness Criteria for Land/Seabed. These are shown in the table below:

All Technologies (Except Non-GB, OHAs and Interconnectors)	Non-GB, OHAs and Interconnectors
Secured the rights to lease or own the land/seabed (or already leases or owns the land/seabed) of the site on which the project is planned to be located as set out in the NESO guidance document.	Secured the rights to lease or own the land (or already leases or owns the land) for the Onshore Converter Substation i.e. in relation to HVDC connected projects. (In the unlikely event there is not to be an onshore converter substation for such projects - i.e. in relation to HVAC connected projects - this will be agreed on a case-by-case basis with NESO. This could include an Agreement for Lease, assessed under the criteria set out in Section 4 above.)

Other Differences of Approach Innovation and Targeted Oil & Gas (INTOG) Projects
Secured relevant conditional seabed rights (for the site on which the project is planned to be located) through an agreement awarded by Crown Estate Scotland (CES) as a result of the INTOG Leasing Round.

5. Gate 2 Readiness Criteria – Planning

This section sets out the Gate 2 Readiness Criteria if seeking to meet Gate 2 Readiness Criteria via evidence of submission and validation of the application for planning

5.1 Gate 2 Readiness Criteria – Planning

We would expect the majority of projects to evidence meeting Gate 2 Readiness Criteria through the land route as per Section 4; however, this planning alternative allows projects that follow the DCO process (including to be granted Compulsory Purchase Order powers) an alternative route to meeting the Gate 2 Readiness Criteria.

The evidence requirement is:

- Submission of (and validation of) application for planning consent for projects following the Development Consent Order (DCO) process i.e. meeting the requirements of Queue Management Milestone M1 via DCO only.
- Other planning consent routes **(in exceptional circumstances)**

Where a User pre-agrees with NESO or the DNO/Transmission Connected iDNO, ahead of the Gated Application Window opening, that they need to follow an alternative planning process (other than the DCO planning route) in order to be granted Compulsory Purchase Order powers to secure relevant land rights, NESO or the DNO/Transmission Connected iDNO may apply discretion on a case-by case-basis in respect of this aspect of the Gate 2 Readiness Criteria (in line with the above evidence requirement). If this is agreed ahead of the Gated Application Window opening, Users will then need to provide in their Readiness Declaration evidence of meeting the requirements of Queue Management Milestone M1 for the appropriate planning route.

5.2 Gate 2 Readiness Criteria – Planning

When is evidence of secured land rights required?

- Considering that this route to meeting Gate 2 Readiness is meeting Queue Management Milestone M1, the ongoing compliance associated with Queue Management Milestone M1 (as referred in section 7.1 of this Gate 2 Criteria Methodology) would not be applicable. However, Users would still need to maintain compliance with Queue Management Milestones - this includes provision of Queue Management Milestone M3 (Secure Land Rights) which is the land route to meeting the Gate 2 Readiness Criteria.
- The Original Red Line Boundary and evidence of minimum acreage requirements (as set out in section 4 of this Gate 2 Criteria Methodology) must be provided as part of evidence of meeting Queue Management Milestone M2. The ongoing land compliance requirements against the Original Red Line Boundary (as referred in section 7.1 of this Gate 2 Criteria Methodology) will therefore apply from when the User has met Queue Management Milestone M2.
    - Note: Users seeking to meet the Gate 2 Readiness Criteria through the planning route that have met Queue Management Milestone M2 at the time of submitting the Readiness Declaration (or where they meet it prior to signature of the Gate 2 Offer) only need to provide the Original Red Line Boundary, installed capacity and evidence of minimum acreage requirements upon their signature of the Gate 2 Offer.

6. Gate 2 Strategic Alignment Criteria

This section references the Gate 2 Strategic Alignment Criteria, one of which the User must meet

6.1 Gate 2 Strategic Criteria – Overview

In addition to meeting the Gate 2 Readiness Criteria (under either Section 4 or 5 of this Gate 2 Criteria Methodology), Users will need to meet one of the following Gate 2 Strategic Alignment Criteria.

Projects will meet the Strategic Alignment Criteria by either being:

a) eligible for relevant 'protections' as set out in section 6.2; or
b) aligned to the capacities within the CP30 Action Plan as described in the Connections Network Design Methodology; or
c) designated as described in the Project Designation Methodology; or
d) a project not within scope of the CP30 Action Plan and of a technology type listed in the table in section 6.3.

Strategic Alignment Criteria a) is evidenced by the User unless set out otherwise in Section 6.2 and the User will need to confirm the Transmission Entry Capacity/Developer Capacity that they are seeking protections against on the Readiness Declaration they submit (Section 9).

For Strategic Alignment Criteria a), b) and d), the User must provide their technology type(s) via the Readiness Declaration they submit (see Section 9). Further clarity on Strategic Alignment Criteria b) and d) is set out in Section 6.3.

The User will meet the requirements of Strategic Alignment Criteria c) where NESO have designated a project, in accordance with the Project Designation Methodology.

If, for a staged or hybrid project, one stage or technology of the project is deemed to meet the Gate 2 Strategic Alignment Criteria and another is not, then the User will be issued with an offer only for the Gate 2 stage or technology of the project (unless identified as a Child technology as set out in Section 7.8.6 of the CNDM). For the avoidance of doubt under CMP434, and as per CUSC Section 17, only a Competent Gate 1 Application results in a Gate 1 Offer.

NESO will confirm to the User if they meet one of these criteria prior to the start of the Gated Design Process. If the User has met the Gate 2 Readiness Criteria and the Gate 2 Strategic Alignment Criteria, detailed checks will be carried out on that User's Gate 2 Readiness Criteria Evidence in the Gated Design Process. This is explained further in Section 8 of this Gate 2 Criteria Methodology.

For projects that are connected to a DNO or Transmission Connected iDNO, assessment against Strategic Alignment Criteria b) will be conducted by NESO on behalf of the DNO or Transmission Connected iDNO.

6.2 Strategic Alignment Criteria (a) – Protections

Eligible for relevant 'protections'

Although the User is not required to do so, if they wish to be considered eligible for Strategic Alignment Criteria a), they will need to provide additional evidence as part of their Gate 2 Application. This is set out in this section, with the NESO's checks on this evidence set out in Section 8.8 of this Gate 2 Criteria Methodology.

The evidence requirements are set out in this section 6.2 for the following protections and are summarised at the end of this section 6.2:

- Protection Clause 2b: Projects which are significantly progressed;
- Protection Clause 3a: Projects which submitted a planning application on or before 20th December 2024 and have since obtained planning consent (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone); and
- Protection Clause 3b: Projects which submitted a planning application on or before the closure of the CMP435 Gated Application Window (26 August 2025) and have since obtained planning consent (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone).

Protection Clause 3a and Protection Clause 3b only apply to Users who had Existing Agreements in relation to CMP435 and supplied evidence of meeting the Gate 2 Readiness Criteria (for the technology type(s) listed in that Existing Agreement) in the CMP435 Gated Application Window in relation to those Existing Agreements (this is what is meant by 'those who reapply in CMP434 only' above). However, this requirement will not be applied where the technology type seeking Gate 2 is in an undersubscribed technology zone.

The User will also need to confirm the Transmission Entry Capacity/Developer Capacity/Demand Capacity that they are seeking protections against and the technology type(s) on the Readiness Declaration they submit (see Section 9).

The following clauses apply in relation to the Gate 2 Strategic Alignment Criteria (a) only. **All Users will still be required to evidence that their project meets the Gate 2 Readiness Criteria** under either Section 4 or 5 of this Gate 2 Criteria Methodology, unless their project is selected by NESO for Gate 1 connection point and capacity reservation.

For the avoidance of doubt, Project technology stages which hold Gate 2 Agreements, or which are already in the process of being offered a Gate 2 Agreement, will not be able to better their allocated queue position by applying for these Protections.

Protection Clause 2b: Projects which are significantly progressed

Any project that meets the following conditions will be deemed to have met the Gate 2 Strategic Alignment Criteria. This clause guarantees a place in the CMP434 queue, even if the project exceeds the zonal or GB permitted capacity for its technology type (as set out within the CP30 Action Plan).

This clause applies to any application where the User can demonstrate one of the following prior to the closure of the CMP434 Gated Application Window:

i. Holding a Contract for Difference (CfD) issued in accordance with the Energy Act 2013; or

ii. Holding a Capacity Market contract issued in accordance with the Energy Act 2013 and relevant secondary legislation; or

iii. Has regulatory approval from the Authority, in the form of either an LDES, Interconnector or OHA Cap and Floor agreement or Merchant Interconnector approval (via the relevant exemptions process with the Authority)[1]; or

iv. Holding a live contract with NESO awarded through their 'Network Services' (previously referred to as 'NOA Pathfinders') processes e.g. Voltage Network Services, Stability Network Services or Constraint Management Intertrip Services[1]; or

v. Being the successful bidder(s) in an offshore wind leasing round process managed by Crown Estate Scotland or The Crown Estate, where such offshore wind leasing round process is associated with a co-ordinated network design process undertaken by NESO aligned with (or where prior analysis indicates, likely to be aligned with) the SSEP when it is published. NESO will confirm this is in writing with the relevant successful bidder(s) and Crown Estate Scotland or The Crown Estate accordingly[1].

Where the support contracts in conditions i) to iv) are dependent on the project connecting by a certain date or within a certain date range, NESO and TOs will use best endeavours to provide a connection date that meets these requirements.

[1] Where a project has not met the Gate 2 Readiness Criteria, but NESO choose to reserve a connection point and capacity for it under the Gate 1 Connection Point and Capacity Reservation provision, this clause will also be applied if the project meets condition iii), iv) or v) to treat the queue position of the reservation as 'protected' for the purpose of queue formation.

Protection Clause 3: Projects which obtain planning consent prior to the closure of the CMP434 Application Window, having submitted a planning application on or before a specified date (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone)

Protection Clause 3a: Projects which submitted a planning application on or before 20th December 2024 and have since obtained planning consent (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone).

This clause applies to projects where the User had submitted an application for Planning Consent on or before 20th December 2024 and has since received planning consent (i.e. Queue Management M2) prior to the closure of a CMP434 Application Window. For the avoidance of doubt, an application that was submitted on or before 20th December 2024 but that was not yet validated by the Statutory Planning Authority would also qualify i.e. the requirements of Queue Management M1 do not need to have been met by 20th December 2024.

Projects benefitting from Protection Clause 3a **will be allowed to exceed both the zonal and GB permitted capacities** (as set out within the CP30 Action Plan) for the relevant technology.

Protection Clause 3b: Projects which submitted a planning application on or before the closure of the CMP435 Gated Application Window and have since obtained planning consent (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone).

This clause applies to projects where the User had submitted an application for Planning Consent that had been validated (i.e. Queue Management M1) on or before the closure of the **CMP435** Gated Application Window (26 August 2025) and has since received planning consent (i.e. Queue Management M2) prior to the closure of a CMP434 Application Window.

Projects benefitting from Protection Clause 3b **will only be required to adhere to the GB total permitted capacity** (as set out within the CP30 Action Plan) for the relevant technology. Where there is a zonal permitted capacity outlined for the technology, and this is exceeded, the project will still receive a Gate 2 offer provided it does not exceed the GB total permitted capacity.

See Section 7 of the CNDM for how these projects will be ordered in the CMP434 queue formation exercise.

For the avoidance of doubt, Protection Clause 3 is not applicable to any projects which do not require planning consent.

Additional notes for protections

Protection for part of a project

If a User has only obtained planning consent or secured a support contract for part of a project, then **only that part will benefit from protection** under any of the clauses outlined in this section. As a result, there may be instances where both parts of the project meet the Gate 2 Strategic Alignment Criteria but receive different queue positions as a result of the queue formation process. There may also be instances where only the protected part of the project receives a Gate 2 offer and not the remainder of the project.

Summary of evidence required to be provided by the User – Protection Clause 2b

Protection Clause 2b: Projects which are significantly progressed	Notes:
• Provide evidence of holding a "live" Contracts for Difference Contract; or "live" Capacity Market Contract; or "live" Cap and Floor agreement or Merchant Interconnector approval (via the relevant exemptions process with the Authority); or "live" contract with NESO awarded through their 'Network Services' processes e.g. Voltage Network Services, Stability Network Services or Constraint Management Intertrip Services; or being the successful bidder in an offshore leasing round associated with co-ordinated network design undertaken by NESO aligned with (or where prior analysis indicates, likely to be aligned with) the SSEP when it is published.	• User will need to confirm the Transmission Entry Capacity/Developer Capacity/Demand Capacity that they are seeking protections against; and state the technology type on the Readiness Declaration they submit.

Summary of evidence required to be provided by the User – Protection Clause 3a and 3b

Protection Clause 3a: Projects which submitted a planning application on or before 20th December 2024 and have since obtained planning consent (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone)

- Provide evidence (i.e. the planning reference number) that the application for planning consent was submitted to the Statutory Planning Authority on or before 20th December 2024; and
- Provide evidence of meeting Queue Management Milestone M2.

Protection Clause 3b: Projects which submitted a planning application on or before the closure of the CMP435 Gated Application Window (26 August 2025) and have since obtained planning consent (those who reapply in CMP434 only, unless the technology type is in an undersubscribed technology zone)

- Provide evidence of meeting Queue Management Milestone M1, noting this must also show this was validated by the Statutory Planning Authority prior to the closure of the CMP435 Gated Application Window (i.e. on or before 26 August 2025); and
- Provide evidence of meeting Queue Management Milestone M2.

Notes:

On Queue Management Milestones

- User must provide evidence whether or not the project is currently subject to Queue Management and whether or not they have previously met the corresponding milestone(s).
- The evidence requirements for these milestones are detailed in the relevant Queue Management guidance (transmission or distribution) unless otherwise stated.

On Protections

- User will need to confirm the Transmission Entry Capacity/Developer Capacity/Demand Capacity that they are seeking protections against; and state the technology type on the Readiness Declaration they submit.

6.3 Strategic Alignment Criteria (b) and (d)

The table below shows the technologies that are in and out of scope of the CP30 Action Plan. In scope technologies must be assessed against the 2030 and 2035 capacity ranges as outlined in CNDM Section 7.4 before they can be deemed to have met the Gate 2 Strategic Alignment Criteria.

- Technologies that are listed in this table and are **not** in scope of the CP30 Action Plan will automatically meet the Gate 2 Strategic Alignment Criteria (under Strategic Alignment Criteria (d)).
- Any technologies **not** listed in this table will only be able to meet the Gate 2 Strategic Alignment Criteria by meeting Strategic Alignment Criteria (a) or (c).

Technology	In scope of CP30 Action Plan?	Breakdown in CP30 Action Plan
Offshore Wind	Yes	GB-wide
Onshore Wind	Yes	Zonal[1]
Solar	Yes	Zonal[2]
Nuclear	Yes	GB-wide
Low Carbon Dispatchable Power	Yes	GB-wide
Unabated Gas	Yes	GB-wide
Long Duration Energy Storage (LDES)	Yes	GB-wide
Batteries	Yes	Zonal
Interconnectors	Yes	GB-wide

Technology	In scope of CP30 Action Plan?
Transmission-Connected Demand	No
Wave	No
Tidal	No
Run-of-river Hydro	No
Geothermal Power	No
Non-GB Generation	No
Reactive Compensation	No

The below table lists all technology definitions provided in the CP30 Action Plan Connections reform annex and additional technology definitions where required to provide further clarity. Technologies listed in this table and the table on the previous page will be kept under review and updated as required if definitions are updated or as new technology types emerge.

Technology	Definition
Low Carbon Dispatchable Power	Low Carbon Dispatchable Power technologies are ones which combust fuel to produce electricity and, by varying the rate at which fuel is burned, can respond to meet the needs of the grid with varying levels of flexibility. This category includes biomass, power BECCS, gas CCUS and hydrogen.
LDES	As outlined in DESNZ and Ofgem's Long Duration Electricity Storage: Technical Decision Document, an LDES asset must be capable of discharge at full power for at least eight hours, and full power must be at least 50MW or 100MW (depending on technology maturity). This also states that for the purposes of the Clean Power 2030 Action Plan pathway which will be used for connections, lithium-ion electricity storage projects will be treated as batteries.
Batteries	Refers to battery storage projects which do not meet the definition of LDES, as per the forthcoming LDES Technical Decision Document.
Nuclear	For the purposes of strategic alignment this means generating stations that use one of the following technologies: Advanced Gas Cooled Reactors, European Pressurised Reactors and Standardised Nuclear Unit Power Plant System Pressurised Water Reactors as projects using these technologies are referenced in Government's plan and are connected, in construction or post planning consent.
Non-GB Generation	Generation located outside of Great Britain and the UK's Exclusive Economic Zone, but which is directly connected to the GB Transmission System or Distribution System and is not connected to another market.
Run-of-river Hydro	Facility that channels flowing water from a river through a canal or penstock to spin a turbine. Typically, a run-of-river project will have little or no storage facility. Run-of-river provides a continuous supply of electricity (base load), with some flexibility of operation for daily fluctuations in demand through water flow that is regulated by the facility.
Geothermal Power	Geothermal power plants use steam to produce electricity. The steam comes from reservoirs of hot water found a few miles or more below the earth's surface. The steam rotates a turbine that activates a generator, which produces electricity.
Reactive Compensation	Reactive Compensation is the process of managing reactive power in electrical systems to improve efficiency, stability, and voltage quality. Note that this also applies to projects categorised as 'Synchronous Compensation', which fall under the 'Reactive Compensation' technology term.

7. Gate 2 Criteria – Ongoing Compliance

This section summarises the ongoing compliance requirements in respect of land and planning

7.1 Gate 2 Criteria – Ongoing Compliance

Once a project has met the Gate 2 Criteria and the User has signed the Gate 2 Offer, there will be ongoing compliance requirements regarding the land and planning. These obligations are set out in CUSC Section 16 and expanded on further in the Queue Management Guidance.

If following the Planning route to meeting Gate 2 Readiness, the ongoing land compliance requirements will apply from when the User has met Queue Management Milestone M2 and as the Planning route to meeting Gate 2 Readiness is meeting Queue Management Milestone M1, the ongoing compliance referenced below associated with Queue Management Milestone M1 is not applicable.

Land

Whatever Installed Capacity in MW (expressed in whole MW or to one decimal place) is built within the Original Red Line Boundary, only 50% of that number can then be located outside of the Original Red Line Boundary. Where this Original Red Line Boundary MW calculation results in a number that is less than the total Installed Capacity, the total Installed Capacity will be reduced accordingly (and this may result in a Transmission Entry Capacity reduction). This is set out further in CUSC Schedule 2 Exhibit 3 Clause 7.5 (Onshore) and CUSC Schedule 2 Exhibit 3A Clause 7.4 (Offshore) in respect of directly connected projects.

Planning

As set out in CUSC Section 16, requirement to submit the application for planning consent (unless already met at the time of the Gate 2 Application) at the earliest of:

i) the Queue Management Milestone M1 ("M1") calculated back from the contracted completion date; or
ii) M1 calculated forwards from the Gate 2 offer date (based on an agreed standard time period calculated from the date of the Gate 2 offer for each planning type) to move from Queue Management Milestone M3 ("M3") to M1.

The requirements to meet Queue Management Milestones will continue to apply.

Note that Embedded Power Stations' Queue Management Milestones and ongoing land compliance requirements will continue to be managed by DNOs or Transmission Connected iDNOs.

8. Gate 2 Criteria Evidence Assessment

This section sets out the Gate 2 Criteria Evidence assessment process including what is being checked and by whom. This includes the assessment process for the Gate 2 Readiness Criteria and Gate 2 Strategic Alignment Criteria

Where a User applies for a technology type under Strategic Alignment Criteria b), in a technology zone which is oversupplied both zonally and nationally then NESO, Transmission Connected iDNOs and/or DNOs reserve the right to indicate that the relevant project technology stage(s) have failed strategic alignment before carrying out any of the initial and detailed checks, and prior to the queue formation process. This does not apply where the User is seeking Strategic Alignment Criteria a) (Protections) or has obtained Strategic Alignment Criteria c) (Project Designation), or has met Strategic Alignment Criteria d).

8.1 Summary of Gate 2 Criteria Evidence Assessment – Summary of Evidence Requirements

User (Transmission Connected and Large Embedded Generation) to NESO	
Evidence Requirement	**Section in Gate 2 Criteria Methodology**
Readiness Declaration	Section 9
Original Red Line Boundary if seeking to meet Gate 2 Readiness criteria through land as per Section 4.1b of this Gate 2 Criteria Methodology • Note if meeting Gate 2 Readiness Criteria through planning route, the above will be provided at Queue Management Milestone M2	Section 4.1b
Evidence of secured land rights (can be redacted to address commercial concerns) as per Section 4.1c of this Gate 2 Criteria Methodology; or submission of planning readiness criteria as per Section 5 of this Gate 2 Criteria Methodology	Section 4.1c (Land); Section 5 (Planning)
Evidence of meeting Strategic Alignment Criteria (if applicable)	Section 6.2 (for a). As per Section 6.1, Strategic Alignment Criteria (c) met where NESO have designated a project, in accordance with the Project Designation Methodology.
+ Gate 2 Application + Large Embedded Generation must have met requirements under Clause 17.6.8 of the CUSC	

8.2 Summary of Gate 2 Criteria Evidence Assessment – Summary of Evidence Requirements

User (Small and Medium Embedded Generation*) to DNO/Transmission Connected IDNO	
Evidence Requirement	**Section in Gate 2 Criteria Methodology**
Readiness Declaration	Section 9
Original Red Line Boundary if seeking to meet Gate 2 Readiness criteria through land as per Section 4.1b of this Gate 2 Criteria Methodology • Note if meeting Gate 2 Readiness Criteria through planning route, the above will be provided at Queue Management Milestone M2	Section 4.1b
Evidence of secured land rights (can be redacted to address commercial concerns) as per Section 4.1c of this Gate 2 Criteria Methodology; or submission of planning readiness criteria as per Section 5 of this Gate 2 Criteria Methodology	Section 4.1c (Land); Section 5 (Planning)
Evidence of meeting Strategic Alignment Criteria (if applicable)	Section 6.2 (for a). As per Section 6.1, Strategic Alignment Criteria (c) met where NESO have designated a project, in accordance with the Project Designation Methodology.
+ must have met requirements under Clause 17.6.8 of the CUSC	

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.3 Summary of Gate 2 Criteria Evidence Assessment – Summary of Evidence Requirements

DNO/Transmission Connected IDNO (on behalf of Small and Medium Embedded Generation*) to NESO	
Evidence Requirement	**Section in Gate 2 Criteria Methodology**
Upon request from NESO, Readiness Declaration(s) that were provided to DNO/Transmission Connected iDNO for Small and Medium Embedded Generation*	Section 9
Provide the Grid Coordinates for the Original Red Line Boundaries that were provided to DNO/Transmission Connected iDNO for Small and Medium Embedded Generation*. Upon request from NESO, provide the actual Original Red Line Boundaries as per Section 4.1b of this Gate 2 Criteria Methodology	Section 4.1b
+ Gate 2 Application	

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.4 Gate 2 Criteria Evidence Assessment – Level of checking

Checking of Gate 2 evidence undertaken prior to Gate 2 Offer

NESO for transmission connected and Large Embedded Generation

As set out in CUSC Section 17.10, there is a reasonable endeavours obligation to check 100% of Gate 2 Readiness Criteria evidence provided and an obligation to publish after the end of the Gated Design Process the percentage of detailed checks undertaken as a percentage of the total of Gate 2 Applications within the Gated Design Process that NESO, DNOs and IDNOs have carried out.

Conduct 100% of duplication checks (Original Red Line Boundaries for Gate 2 applications including those for Small and Medium Embedded Generation* and those that have already met the Gate 2 Criteria).

DNO/Transmission Connected iDNO for Small and Medium Embedded Generation*

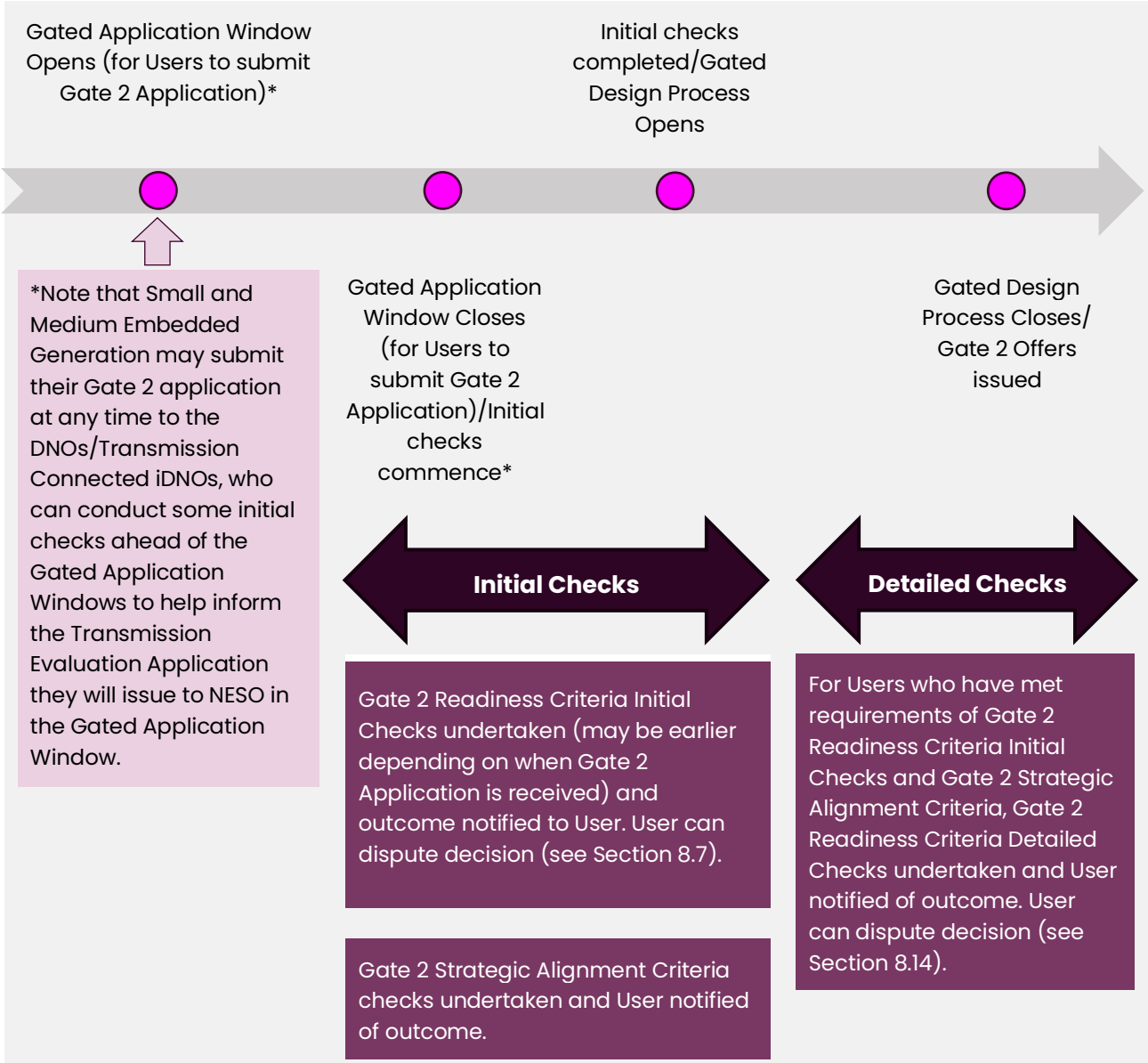
As set out in CUSC Section 17.10, there is a reasonable endeavours obligation to check 100% of Gate 2 Readiness Criteria evidence provided and obligation to inform NESO after the end of the Gated Design Process the percentage of detailed checks undertaken as a percentage of the total of Gate 2 Applications within the Gated Design Process for their licensed area.

Upon request from NESO, provide copies of Readiness Declaration(s) for Small and Medium Embedded Generation* that they believe have met the Gate 2 Readiness Criteria, but it will still be the DNO/Transmission Connected iDNO that assesses these. Note that the data submission(s) (which includes data from the Readiness Declarations), that is provided by the DNO/Transmission Connected IDNO to NESO associated with the Gated Application Window, is considered to meet the CUSC requirement for DNO/Transmission Connected IDNOs to provide the Readiness Declarations.

Provide Grid Coordinates for the Original Red Line Boundaries to NESO for Small and Medium Embedded Generation* that they believe have met Gate 2 Readiness Criteria. Also, upon request from NESO, provide any requested Original Red Line Boundaries they have received. (NESO will carry out duplication checks against these Original Red Line Boundaries).

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.5 Gate 2 Criteria Evidence Assessment – Timing of Checks



8.6 Gate 2 Criteria Evidence Assessment – Initial Checks (Gate 2 Readiness Criteria)

Initial checks – Gate 2 Readiness Criteria

These will be carried out prior to the start of the Gated Design Process. These checks will be carried out by NESO apart from in respect of Small and Medium Embedded Generation*, which are undertaken by their DNO/Transmission Connected iDNO. Note that as Small and Medium Embedded Generation can submit their Gate 2 application at any time, the DNOs/Transmission Connected iDNOs could conduct some initial checks ahead of the Gated Application Window.

Below is a list of the Gate 2 Criteria Readiness initial checks that we will undertake. We will keep under review if any of the Gate 2 Criteria Readiness detailed checks as set out in section 8.91. 8.11. 8.12 or 8.13 can be carried out prior to the start of the Gated Design Process.

Evidence provided by User	Check
Readiness Declaration	All mandatory fields completed
Received the Gate 2 Readiness Criteria Evidence – land or planning?	Check document can be opened and is a land/planning document
Received Original Red Line Boundary *(if meeting Gate 2 Readiness Criteria through secured land rights)*	Check it can be opened and is a red line boundary and includes all the mandatory information as set out in 4.1b of this Gate 2 Criteria Methodology
Connection Application or Modification Application	Application is Competent as per CUSC Section 11

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.7 Gate 2 Criteria Evidence Assessment – Initial Checks (Gate 2 Strategic Alignment Criteria)

Initial checks – Gate 2 Strategic Alignment Criteria

As well as the Gate 2 Readiness Criteria initial checks, there will be Gate 2 Strategic Alignment Criteria checks (as set out in Section 6, of this Gate 2 Criteria Methodology) undertaken prior to the start of the Gated Design Process. Below is a list of the Gate 2 Strategic Alignment Criteria checks:

Strategic Alignment Criteria	Carried out by NESO	Carried out by DNO/Transmission Connected IDNO
a) eligible for relevant 'protections' as set out in section 6.2 of this Gate 2 Criteria Methodology	Yes, see section 8.7 of this Gate 2 Criteria Methodology	Yes, see section 8.7 of this Gate 2 Criteria Methodology
b) aligned to the capacities within the CP30 Action Plan as described in the CNDM	Yes, as set out in the Connections Network Design Methodology and carried out by NESO on behalf of the DNO or Transmission Connected iDNO	No, carried out by NESO on behalf of the DNO or Transmission Connected iDNO
c) designated as described in the Project Designation Methodology	Yes, as set out in the Project Designation Methodology	N/A – although if a DNO/Transmission Connected iDNO identifies a Small or Medium Embedded Generation* project, which they believe should be designated, they can notify NESO
d) a project not within scope of the CP30 Action Plan and of a technology type listed in the table in section 6.3	As per Strategic Alignment Criteria b)	As per Strategic Alignment Criteria b)

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

Initial checks – Gate 2 Strategic Alignment Criteria

Although the User is not required to do so, if they wish to be considered eligible for Strategic Alignment Criteria a), they will need to provide additional evidence as part of their Gate 2 Application as set out in section 6.2. These checks will be carried out by NESO apart from in respect of Small and Medium Embedded Generation*, which are undertaken by their DNO/Transmission Connected iDNO. These checks are:

- Verifying evidence of meeting Queue Management Milestones M1 and M2 (for Protections 3a and 3b) in accordance with the checks detailed in the relevant Queue Management Guidance (Transmission or Distribution).
- Where the User evidences that they hold a "live" Contract for Difference (CfD); or "live" Capacity Market (CM) Agreement; or have "live" Cap and Floor arrangements in place (or Merchant Interconnector approval via the relevant exemptions process with the Authority) or have a "live" contract with NESO awarded through its 'Network Services' processes; or are a successful bidder in an offshore leasing round (but only where this is as described in Section 6.2). This will be checked by NESO or DNO/Transmission Connected iDNO with the body that issued these i.e.
    - LCCC for CfD; or
    - NESO for CM, Network Services Contract and if a successful bidder in an offshore leasing round (but only where this is as described in Section 6.2); or
    - the Authority for Cap and Floor arrangements; and/or
    - through a review of public information e.g. there is a CfD and CM register, etc.

Note that for Strategic Alignment Criteria a), b) and d), the User needs to provide their technology type(s), via their Readiness Declaration, and this will be verified (where relevant) against the existing agreement. Additionally for Strategic Alignment Criteria a), the User will need to confirm the Transmission Entry Capacity/Developer Capacity/Demand MWs that they are seeking protections against via their Readiness Declaration, noting that If a User has only obtained planning consent or secured a support contract for part of a project, then only that part will benefit from protection - this will also be verified.

As per Section 6.1, Strategic Alignment Criteria (c) is met where NESO have designated a project, in accordance with the Project Designation Methodology.

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

Initial checks – Gate 2 Readiness Criteria and Gate 2 Strategic Alignment Criteria

Apart from Small and Medium Embedded Generation*, NESO will notify the User if they have met the Gate 2 Readiness Criteria initial checks and Gate 2 Strategic Alignment Criteria. The DNO/Transmission Connected iDNO will do likewise in respect of the Small and Medium Embedded Generation* that has applied to them in the Gated Application Window.

This notification would be issued prior to the start of the Gated Design Process.

All Users who have met the requirements of the Gate 2 Readiness Criteria initial checks and the Gate 2 Strategic Alignment Criteria will be taken forward into the Gated Design Process (assuming a competent application). They will be assumed (due to their Readiness Declaration) to have met the Gate 2 Readiness Criteria unless they subsequently do not meet the Gate 2 Readiness Criteria detailed checks.

All Users who do not meet the Gate 2 Readiness Criteria initial checks prior to the start of the Gated Design Process can dispute that decision* but will not be included in the Gated Design Process.

A User can dispute the NESO's decision in accordance with CUSC Section 7.4. Note that for Small and Medium Embedded Generation*, it would be the DNO/Transmission Connected iDNO that makes the decision on whether the User meets the Gate 2 Readiness Criteria so these Users would raise their dispute to the DNO/Transmission Connected iDNO. If the User does raise a dispute, the next steps for their application will be determined by the outcome of the dispute process.

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.8 Gate 2 Criteria Evidence Assessment – Detailed Checks (Gate 2 Readiness Criteria)

Detailed checks – Gate 2 Readiness Criteria

All Users who have met the requirements of the Gate 2 Readiness Criteria initial checks and the Gate 2 Strategic Alignment Criteria will be taken forward into the Gated Design Process (assuming a competent application). They will be assumed (due to their Readiness Declaration) to have met the Gate 2 Readiness Criteria unless they subsequently do not meet the Gate 2 Readiness Criteria detailed checks, which will be undertaken up until the end of the Gated Design Process, although we aspire to do these as early as possible within the Gated Design Process. Below is a list of the Gate 2 Criteria Readiness Detailed checks and who is responsible for checking:

Check	Who
Verification of Director(s) that signed the Readiness Declaration	NESO, apart from in respect of Small and Medium Embedded Generation*, which are undertaken by their DNO/Transmission Connected iDNO
Overlapping Original Red Line Boundaries ("Duplication Check")	NESO (including in respect of Small and Medium Embedded Generation*)
Secured Land Rights Evidence meets minimum acreage requirements as set out in section 4.1a and requirements as set out in section 4.1c	NESO, apart from in respect of Small and Medium Embedded Generation*, which are undertaken by their DNO/Transmission Connected iDNO
Evidence of submission and validation of application for planning consent i.e. meeting the requirements of Queue Management M1	NESO, apart from in respect of Small and Medium Embedded Generation*, which are undertaken by their DNO/Transmission Connected iDNO

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.9 Gate 2 Criteria Evidence Assessment – Detailed Checks (Verification of Director(s) that signed the Readiness Declaration Letter)

Verify that the Director, for Limited and plc companies is active on Companies House at the time of their Gate 2 Application.

If a company is not listed on Companies House, we will utilise publicly available information to verify authorised individuals. However, we recommend that a Covering Letter is provided if clarification is required regarding an organisation, including where a change of ownership could happen whilst the Gate 2 Application is progressing.

If the verification check is failed, then the User does not meet the Gate 2 Readiness Criteria and they will not receive a Gate 2 Offer (however, they are not precluded from applying into the next Gated Application Window).

The User may be asked to clarify evidence, but they cannot submit new evidence e.g. the User cannot send a new Readiness Declaration with a different Director signing it.

The same Director that signed the Readiness Declaration should sign any clarified evidence, but where this is not possible / practicable a different Director can sign clarified evidence (or an authorised person, as set out in Section 9 below).

A User can dispute NESO's decision in accordance with CUSC Section 7.4. Note that for Small and Medium Relevant Embedded Generation, it would be the DNO/Transmission Connected iDNO that makes the decision on whether the User meets the Gate 2 Readiness Criteria so these Users would raise their dispute to the DNO/Transmission Connected iDNO.

8.10 Gate 2 Criteria Evidence Assessment – Detailed Checks (Overlapping Original Red Line Boundaries ("Duplication Check")

Original Red Line Boundaries provided and any overlapping boundaries identified

NESO contacts all the Users where boundaries overlap and seeks clarity from the Users. As there is an opportunity to explain overlaps on the Readiness Declaration templates, which we encourage Users to do, we will first check the Readiness Declaration templates for any explanation of overlaps before reaching out to the parties involved. If there is no explanation on Readiness Declaration templates or it is not clear, then we will conduct further enquiries with all Users where it is not reasonably demonstrable that the same land can be used by two or more different Users/projects.

If such an overlap can be demonstrated as being reasonably possible (in relation to that same land being able to be used by two or more different Users/projects), then the overlap will be acceptable from the Gate 2 Readiness Criteria perspective. This decision will be at the discretion of NESO using reasonable judgment based on the evidence presented by the different Users/projects.

In the event an overlap is deemed to be unacceptable by NESO, impacted Users will be further required to submit specific information to confirm their appropriate right to the land within their relevant Original Red Line Boundary. Such information may include a signed letter of confirmation from the landowner(s) to NESO confirming the appropriate User that should be utilising the land. The User that is not able to provide such confirmation statement(s) will be deemed to not have met the Gate 2 Readiness Criteria.

NESO will confirm any overlaps which interact with Small and Medium Embedded Generation's* Original Red Line Boundaries and in this scenario will seek support from DNOs/Transmission Connected iDNOs to help resolve.

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.11 Gate 2 Criteria Evidence Assessment – Detailed Checks (Secured Land Rights Evidence meets minimum acreage requirements)

Verify that each Original Red Line Boundary provided (under 4.1b of this Gate 2 Criteria Methodology) has an acre per MW which meets the minimum acreage requirements Energy Land Density table unless different requirements have been agreed between NESO and User in accordance with the prevailing NESO guidance document.

8.12 Gate 2 Criteria Evidence Assessment – Detailed Checks (Secured Land Rights Evidence meets requirements of 4.1c)

- The secured land rights evidence provided meets the Gate 2 Readiness minimum criteria.
- There are "live" secured land rights in place for all the land at the project site, as shown by the relevant Original Red Line Boundary.
- Technology or Technologies applied for in the Gate 2 Application are not prohibited from being built under the secured land rights evidence.
- The secured land rights (apart from where related to Evidence of Existing Ownership) are signed by both the User and the landowner (or their authorised agent). Where the documentation is not signed by both parties, we will accept the counterpart signed by the landowner(s).
- The User is the party who has entered into the secured land rights or the User has provided a signed letter from the entity who holds the land rights stating that User has the rights to use the land. Where connection agreements are held in one company and the land rights are put in the names of the specific SPV with both these companies under the direct control of the same parent company, we will accept a signed letter from the director or authorised person, to explain the fact that the land rights company and applicant are under control of the same group company.
- There are no landowner unilateral termination provisions included in options and leases, except in the event of default by the tenant.
- The User may be asked to clarify evidence, but they cannot submit new evidence e.g. the User cannot just send a new land Option but may be asked to clarify how the Option meets the criteria (if not clear).
- A party that has been informed that they have not met the Gate 2 criteria can raise a dispute under CUSC Section 7.4. Note that for Small and Medium Embedded Generation*, it would be the DNO/Transmission Connected iDNO that makes the decision on whether the User meets the Gate 2 Readiness Criteria so these Users would raise their dispute to the DNO/Transmission Connected iDNO.

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

As well as reviewing the land rights documentation provided by Users, we may utilise public sources of data (if available) to verify evidence of land rights. We may also explore use of Artificial Intelligence tools to support evidence checks.

8.13 Gate 2 Criteria Evidence Assessment – Detailed Checks (Evidence of submission and validation of application for planning consent (DCO))

Evidence of meeting Queue Management Milestone M1 via DCO only will be verified in accordance with the checks detailed in the relevant Queue Management Guidance (Transmission or Distribution). Checks will ensure that the location of the site, technology and capacity are in line with the Gate 2 Application, and that the application for planning consent is valid.

Where Small and Medium Embedded Generation* seeks to meet the Gate 2 Readiness Criteria through this route, it would need to provide the evidence as set out above to the DNO/Transmission Connected iDNO.

If NESO decide that the User does not meet this Gate 2 Readiness Criteria, the User can dispute NESO's decision in accordance with CUSC Section 7.4. Note that for Small and Medium Relevant Embedded Generation, it would be the DNO/Transmission Connected iDNO that makes the decision on whether the User meets the Gate 2 Readiness Criteria so these Users would raise their dispute to the DNO/Transmission Connected iDNO.

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

8.14 Gate 2 Criteria Evidence Assessment – Detailed Checks (Outcome)

Detailed checks – Gate 2 Readiness Criteria

Apart from Small and Medium Embedded Generation*, NESO will notify the User if they have met the Gate 2 Readiness Criteria detailed checks.

This notification would be by the end of the Gated Design Process, but we will aspire to complete the Gate 2 Readiness Criteria detailed checks as early as possible within the Gated Design Process.

The DNO/Transmission Connected iDNO will do likewise in respect of the Small and Medium Embedded Generation* that has applied to them in the Gated Application Window (although it will be NESO who will notify the DNO/Transmission Connected iDNO on outcome of any overlapping Original Red Line Boundaries (i.e. the "Duplication Check") and then the DNO/Transmission Connected iDNO will need to inform the Small and Medium Embedded Generation* project).

All Users who do not meet the Gate 2 Readiness Criteria detailed checks can dispute that decision, but they will not receive a Gate 2 Offer as part of the Gated Design Process. If a dispute is raised, the next steps for their application will be determined by the outcome of the dispute process.

* Includes Relevant Embedded Small Power Stations, Relevant Embedded Medium Power Stations, Embedded Small Power Stations with a Bilateral Embedded Generation Agreement and Embedded Medium Power Stations with a Bilateral Embedded Generation Agreement.

9. Readiness Declarations

The document that Users will submit to demonstrate Gate 2 Readiness Criteria

9.1 Readiness Declaration – General

The User will need to provide a Readiness Declaration to support how they meet the Gate 2 Criteria. The Readiness Declaration must be signed by a Director of the User applying.

- Where the Director is not a statutory director (i.e. a director of a Company that is not on Companies House), the Director must provide a signed letter stating that they are a person authorised to make this declaration on behalf of the User/Applicant.
- The Director (even if not a statutory director) is allowed to authorise a person to sign the Readiness Declaration on their behalf by providing a letter signed by the Director as part of their Gate 2 application.

Note that Users may also be asked for information in the Readiness Declaration to support Queue Formation (as per the requirements of the Connections Network Design Methodology).

There is a requirement on NESO to publish some information provided in the Readiness Declaration on a Gate 2 Register. The information that needs to be published will be set out in the Readiness Declaration. However, Users will be provided with the opportunity in the Readiness Declaration to opt out of such information being published for their project.

This Readiness Declaration will be published separately to this Gate 2 Criteria Methodology ahead of the Gated Application Window opening and will set out the questions, evidence, supporting notes and clarification as to which fields are mandatory to populate.

NESO and individual DNOs/Transmission Connected iDNOs will confirm how they wish to receive these Readiness Declarations, which may be via a system. However, the requirements as set out in the Readiness Declaration will be the same whichever medium is used.

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Definition of Favourable Conservation Status for barbastelle bat

Defining Favourable Conservation Status Project

[redacted] and Natural England

March 2024

NATURAL ENGLAND

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- [redacted], University of Exeter
- [redacted]
- Members of Natural England's Technical Steering Group in particular [redacted] and [redacted].

Executive summary

This document sets out Natural England's view on favourable conservation status for barbastelle in England.

Favourable conservation status is the minimum threshold at which we can be confident that the species is thriving in England and is expected to continue to thrive sustainably in the future.

This definition has been produced following the Natural England approach to defining favourable conservation status described in the guidance document Defining Favourable Conservation Status in England.

Section 1 of this document describes the species covered by this definition and its ecosystem context.

Section 2 specifies the units used to describe the three favourable conservation status parameters. These are:

- Natural range and distribution (where the species occurs).
- Population (how many there are of the species).
- The extent and quality of habitat supporting the species population.

Section 3 outlines the evidence considered when developing the definition. This definition is based on the best available evidence on the ecology of barbastelle. The evidence covers the current situation, historical changes and possible future changes.

Section 4 sets out the conclusions on the favourable values, that is the value for each of the three parameters when the species has achieved favourable conservation status.

This document does not include any action planning, nor describe actions, to achieve or maintain favourable conservation status. These will be presented separately, for example within strategy documents.

Summary definition of favourable conservation status

Barbastelles are closely associated with broadleaved woodland containing large numbers of veteran and dead trees which provide them with roost sites. Barbastelles predominantly roost under loose bark, switch roosts frequently and require large numbers of roost trees. Roosts can be spread over a large area, typically 100-200 ha.

Barbastelles are specialist hunters of moths and generally forage in woodland and over riparian habitats with a diverse structure supporting large numbers of moths. They can travel up to 20 km from roost sites to preferred foraging areas. They generally avoid built-up areas, appear sensitive to disturbance and are light shy.

Barbastelles are widely distributed through southern and central England, but they are uncommon and occur in low numbers. Their range is highly fragmented, reflecting the distribution of their preferred habitat.

There is considerable uncertainty over the size of the population and how numbers may have changed over time: there are few records prior to 1993 but the number of records has increased considerably in recent years due to the introduction and more widespread use of sensitive acoustic survey equipment capable of detecting their low-amplitude echolocation signals. Habitat suitability modelling suggests the current population may be some 21,000-42,000 bats.

There is some evidence of a contraction in range, with no recent records from Yorkshire, despite an increase in recording effort. Given overall changes in the availability of the preferred habitat, it is possible that supporting habitat has declined and populations of barbastelles have declined in response.

To achieve favourable conservation status, barbastelle populations should increase to 73,000-147,000 individuals, occupying the habitat available across the species' current and historic range. This will necessitate an expansion into six additional counties, new broadleaved woodland and the appropriate management of all potentially suitable habitat for barbastelles across the favourable range.

Table 1 Confidence levels for the favourable values

Favourable conservation status parameter	Favourable value	Confidence in the favourable value
Range and distribution	The current range and distribution plus populations in six additional counties (Cheshire, East Riding of Yorkshire, North Yorkshire, South Yorkshire, Staffordshire and West Yorkshire) where barbastelles are predicted to be present.	**Moderate**
Population	An increase from the current estimated population of 21,000–42,000 individuals in England to 73,000-147,000 individuals.	**Low**
Habitat	The favourable supporting habitat in England is 11,700 km^2 of habitat suitable for barbastelles.	**Low**

As of July 2022, based on a comparison of the favourable values with the current values, barbastelles are not in favourable conservation status. Note, this conclusion is based

solely on the information within this document and not on a formal assessment of status nor on focussed and/or comprehensive monitoring of status.

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About the Defining Favourable Conservation Status project

Natural England's Defining Favourable Conservation Status (DFCS) project is defining the minimum threshold at which habitats and species in England can be considered to be thriving. Our Favourable Conservation Status (FCS) definitions are based on ecological evidence and the expertise of specialists.

Through setting our ambition and aspiration for species and habitats, our definitions will inform decision making and actions to achieve and sustain thriving wildlife.

Our FCS definitions will be embedded into delivery of the 25 Year Environment Plan, through the Nature Recovery Network, biodiversity net gain and environmental land management schemes (ELMS).

Conservation bodies will use them to inform their work, including management planning for the land they own. Businesses will have a clear understanding of how their work impacts nature recovery and how they can help contribute to achieving thriving nature.

By considering the evidence for FCS, decisions will be more confident and strategic, with an understanding of their contribution to, or impact on, the national ambition.

1. Species definition and ecosystem context

1.1 Species definition

Barbastelle or western barbastelle *Barbastella barbastellus*, Schreber 1774.

1.2 Species status

Red list status

An assessment of the risk of extinction.

Global: Near Threatened (Piraccini 2016)

European: Vulnerable (Temple & Terry 2007).

GB: Vulnerable (Matthews & Harrower 2020).

England: Vulnerable (Matthews & Harrower 2020).

Conservation status

- Species of Principal Importance under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006.
- Listed as a Species of Community Interest whose conservation requires the designation of Special Areas of Conservation under the Conservation of Habitats and Species Regulations 2017.
- Listed as a Species of Community Interest in need of strict protection under Annex IV of the Habitats Directive.

1.3 Life cycle

Barbastelles become sexually mature and can breed in their first year of life, although most females probably do not mate for the first time until late summer early in the second year of life (Rydell & Bogdanowicz 1997). Mating occurs predominantly during late summer and early autumn at the entrance to underground sites and in tree cavities, and probably continues to a lesser extent through winter inside hibernacula (Parsons and others 2003; Gottfried 2009). Ovulation and fertilisation are delayed until late winter or early spring, so sperm are stored and possibly nourished in the oviduct or uterus over winter while females are hibernating (Altringham 1996). The gestation period in

barbastelles can vary considerably due to environmental factors that affect food supply, but on average is expected to last between 50 and 60 days. If mothers are prevented from feeding and enter torpor – a state of reduced physiological activity – because of poor weather the gestation period can be lengthened significantly (Altringham 1996).

From early May onwards, reproductive females congregate in trees and occasionally in buildings, forming maternity colonies, while males tend to roost separately, either alone or in small groups. Maternity roosts typically comprise 20-40 adults and occasionally more than 50 adults. Very rarely, colonies comprising over 100 individuals have been recorded (for example, Davidson-Watts 2008). Females usually give birth to one pup from late June through to mid or late July, and occasionally into early August; rarely, twins are born (Rydell & Bogdanowicz 1997). Young develop rapidly and begin to fly at around three weeks. Before then, mothers may carry pups between roosts. At around six weeks, the young are weaned and begin to forage for insects. After weaning, the summer colonies break up as adult females begin visiting mating and hibernation sites. Bats reach adult size within about nine weeks, although the rate of development from birth can vary according to the microclimate within roosts and the availability of food (Altringham 1996; Rydell & Bogdanowicz 1997). The average life expectancy of a barbastelle is between five-and-a-half and ten years, although ringed individuals living for nearly 22 years have been recorded (Abel 1970). As with other bats, mortality is thought to be considerably higher in juveniles than in adults (Unikauskajte 1990; Urbańczyk 1992).

Barbastelles hibernate during winter, typically from November to March. Periodic arousal from hibernation has been observed, presumably allowing bats to meet physiological needs (Hanzal & Průcha 1988; Rydell & Bogdanowicz 1997; Thomas & Geiser 1997), but otherwise little is known regarding winter activity or ecology of barbastelles. Winter roosts can be inside underground sites such as caves or mines, between timbers in buildings, or in tree cavities. Usually, bats are found roosting either alone or in small numbers although in central and eastern Europe hundreds, or rarely thousands, of bats can accumulate in underground hibernacula (Urbańczyk 1991; Uhrin 1995).

1.4 Supporting habitat

The habitat required to maintain populations of barbastelles in England is a combination of the habitat required for roosting, including maternity roosts, temporary roosts and hibernation sites, and that required for foraging.

Roost requirements

Barbastelles are foremost a tree-roosting species, although summer roosts in buildings and other sites are used in landscapes where roosting opportunities in trees are more limited. Preferred roosts are in narrow crevices behind loose bark or in tree cavities or splits, and so the species is closely associated with old growth woodland where veteran and dead trees are numerous (Steinhauser and others 2002; Greenaway 2001; Russo and others 2004; Hillen and others 2010; Zeale and others 2012). Roosts under loose bark are

favoured by barbastelles across Europe and may be selected in part to avoid competition with birds and other mammals that prefer more stable roost structures (Greenaway 2001; Russo and others 2004). It is probably for this reason also that barbastelles are rarely recorded in larger cavities, such as woodpecker holes, which are favoured by other bat species (Boonman 2000; Ruczyński & Bogdanowicz 2008; Dietz & Pir 2009). Roosts have been identified in butt rot cavities as low as 50 cm above ground level and in crevices and cavities more than 20 m above ground (Carr and others 2018).

Roost sites in more open habitats such as parkland and wood pasture are known although maternity colonies are mostly located in woodland with a closed canopy. Even small populations require large numbers of roost trees as barbastelles switch roosts frequently (Russo and others 2005, 2007; Zeale and others 2012). Roosts have been documented in a wide range of tree species, although oak *Quercus* spp. is used most frequently due to its propensity for developing and retaining preferred roost features (Greenaway 2001; Russo and others 2004; Hillen and others 2010; Zeale 2011; Zeale and others 2012; Carr and others 2018). It is important to note, however, that roosts are selected primarily on the characteristics of the roost feature rather than the tree, and so any tree supporting a suitable roost feature may be used (Zeale 2011; Carr and others 2018). Indeed, roosts have been discovered in a wide range of tree size and age classes.

The roost preferences of female bats can vary during the summer according to their reproductive state and changing environmental conditions. In spring and autumn, females are more likely to roost alone or in small numbers and will select roosts that facilitate torpor during periods of poor weather. During the summer, females roost together in greater numbers and select roosts with microclimates that benefit the development of offspring. For example, in some circumstances breeding females have been found to favour roost features with greater exposure to solar radiation, presumably to capitalise on warmer roost micro-climates that can benefit the development of offspring (Russo and others 2004). These preferences have not been observed in populations universally, however, and so selection of roost features in this way is likely to be site-specific. In central Italy, where summers are relatively hot, crevices behind loose bark are used frequently throughout the year and are selected by lactating females as nursery sites for their young (Russo and others 2004). In the UK, the preference for loose bark tends to decrease in mid-summer and cavities are used more frequently (Greenaway 2001; Carr and others 2018), probably because cavities provide more stable microclimates that buffer against colder night temperatures experienced at more northern latitudes (Russo and others 2005; Zeale 2011). During lactation, the rate of roost switching tends to slow and a colony of bats can remain in a single tree roost for up to two weeks, probably to minimise risks associated with moving dependent young to alternative roosts (Russo and others 2005; Carr and others 2016; Carr and others 2018). At other times of the year, barbastelles typically switch roost every 1-3 days (Russo and others 2005; Hillen and others 2010; Zeale and others 2012; Carr and others 2016; Carr and others 2018).

As many as 50 different roosts can be used by a colony in a single summer and roosts can be spread across a large area, typically in the region of 100-200 ha, although up to 500 ha

has been documented. Females display fidelity to roost areas across years, returning to the same woodland each year to give birth and rear young (Hillen and others 2010; Zeale and others 2012). Often the same roosts are used in subsequent years, although many become unsuitable or are lost entirely. Loose bark can become dislodged easily and so a high turnover of new roosts is required to support a colony over multiple years (Russo and others 2004; Zeale 2011). Unmanaged woodland with high structural and floral diversity is considered to be optimal roosting habitat, although ancient woodland sites where a policy of minimum intervention is carried out to restore diversity can be of equal high value, provided that dead trees are retained (Russo and others 2004; Zeale 2011; Carr and others 2018). It is thought that barbastelles are not able to persist in woodland where intensive management and non-selective logging is conducted, although where these habitats exist around optimal roost sites, they can provide additional, albeit limited, roosting opportunities and may be used by bats (Russo and others 2010). Generally, barbastelles are thought to select roost sites away from areas of human disturbance (Russo and others 2004; Zeale 2011).

In landscapes where preferred roost sites are scarce, barbastelles will roost in buildings, including in mortise joints of timber-framed barns, behind wood cladding and wooden window shutters, and rarely in historic churches (Rydell & Bogdanowicz 1997; Schober & Grimmberger 1997). When buildings are occupied by a maternity colony, the colony usually remains in the building throughout the summer, although roost switching between different cavities inside the building usually occurs (Steinhauser and others 2002). In non-forest landscapes, the species has been recorded roosting in rock crevices in cliff walls and occasionally under loose scree (Sierro & Arlettaz 1997; Sierro 1999; Ancillotto and others 2014a, 2014b). Rock crevices can also be used in intensively managed woodland that is largely devoid of preferred roost features (Ancillotto and others 2014a). Barbastelles are rarely recorded in bat boxes, although boxes designed specifically for barbastelles that mimic loose bark have proven successful and boxes can even be adopted in preference to existing natural roosts (Greenaway 2008; Rachwald and others 2018).

Foraging requirements

As specialist hunters of moths, barbastelles forage predominantly in habitats where moth biomass is high and will travel up to 20 km from roost sites to reach productive hunting grounds (Hillen and others 2009; Zeale and others 2012; Ancillotto and others 2014a). Field studies have shown that biomass, rather than diversity, ultimately drives foraging site choice, indicating that barbastelles select areas to maximise ingestion of moths regardless of the variety of species available (Ancillotto and others 2014a). This is supported by molecular diet studies which show that common and abundant moth species are consumed most frequently (Zeale 2011; Carr and others 2021). Barbastelles hunt predominantly where dense vegetation borders open ground, such as woodland edge, treelines, hedgerows, woodland rides, and above woodland canopy, and bats make repeated linear flights back and forth along these edge habitats where moth densities are relatively high (Maudsley 2000; Pywell and others 2004; Merckx and others 2009, 2012).

Barbastelles across Europe commonly exhibit a preference for foraging in woodland and riparian habitats that have high structural diversity (Sierro 1999, 2003; Sierro & Arlettaz 1997; Greenaway 2001; Hillen and others 2009; Zeale and others 2012). These habitats are among the most productive with regard to moths (Kennedy & Southwood 1984; Dodd and others 2008; Salsamendi and others 2012). In agricultural landscapes where preferred habitats are scarce or highly fragmented, open meadows and field boundary features such as treelines and hedgerows contribute significantly to the overall foraging habitat (Greenaway 2008; Hillen 2011; Zeale and others 2012; Davidson-Watts 2014). They have also been recorded foraging along exposed coastal cliffs, although primarily where tall vegetation is present (Harris 2020). Similarly, in non-forested areas of central Italy, where vegetation structure is rare, barbastelles target remaining bankside vegetation along streams that comprises only 1.4% of available habitat (Ancillotto 2014a). Rare cases of barbastelles foraging at streetlights have been documented (Zing 1994), although generally they avoid built-up areas and are considered to be one of the most light-averse bats (Zeale and others 2012). Light pollution is considered a limiting factor for this species (Apoznański and others 2021).

During the spring, when barbastelles roost alone or in small numbers, bats can spend much of the time in torpor. Insect flight activity declines dramatically as ambient temperature falls below 6-10 °C and bats can remain inactive for days at temperatures below 7 °C (Taylor 1963; Jones and others 1995; Zeale 2011). When bats do emerge, they typically forage in woodland close to roosts where the ambient temperature is higher than in the surrounding open countryside and is less likely to fall below the threshold for insect flight (Greenaway 2008; Zeale 2011). During the summer, females can increase their home range area considerably (Zeale and others 2012). Range spans (distance from roost to foraging area) of over 20 km have been recorded in England, although most often bats forage within 7 km of roosts (Greenaway 2001, 2008; Hillen and others 2009; Zeale and others 2012; Ancillotto and others 2014a). Recent research also suggests that the home range areas of breeding females increase in size as they transition from pregnancy through lactation to post-lactation (Greenaway 2008; Hillen and others 2009; Zeale and others 2012). During pregnancy, females have significantly higher wing loading, and so home ranges may be smaller. Lactating females have higher energetic demands than pregnant females, and so larger home range areas during this period have been interpreted as bats exploiting more productive hunting grounds at greater distances from roosts (Greenaway 2008; Hillen and others 2009). However, there is also evidence of barbastelles reducing home range areas in lactation, as research has also suggested for other bat species, possibly because they have to make repeated returns to the roost (Davidson-Watts pers.comm. 2022) In late summer, after young are weaned, females begin visiting mating and hibernation sites that may be many kilometres away from roosts and hunting grounds, and so home ranges can increase considerably (Davidson-Watts & Mckenzie 2006; Zeale and others 2012). It has also been suggested that adult females may increase their home range areas later in the summer to avoid competition with flying young (Steinhauser and others 2002), although it remains unclear whether young bats forage independently from mothers or follow them to hunting grounds. Adult male bats

appear to roost close to their foraging areas throughout the summer, and so generally do not travel more than 1-2 km from roosts, except in late summer when visiting mating sites (Hillen and others 2009).

When maternity colonies form, and barbastelles become highly clustered in the landscape, females display high fidelity to largely private foraging areas that overlap only minimally with those of other colony members (Hillen and others 2009; Zeale and others 2012). Fidelity to foraging sites even extends across years so that bats returning to maternity roosts following hibernation continue to use the same hunting grounds (Hillen and others 2010; Zeale and others 2012). This apparent spatial organisation of foraging sites around maternity roosts probably benefits females by minimising costs associated with repeated searching for profitable hunting grounds and the defence of resources against other colony members (Chaverri and others 2007; Hillen and others 2009). In landscapes where profitable hunting grounds are limited, the partitioning of resources in this way probably explains why there is such disparity in the size of home ranges among colony members (Zeale and others 2012). In extreme cases, two bats tracked at the same time from the same colony had home ranges that differed 20-fold in size, from 200 ha to more than 4,000 ha (Zeale 2011). Generally, though, most home range areas are between 400 and 1,500 ha, making barbastelles one of the widest-ranging bat species for its size (Hillen and others 2009; Zeale and others 2012).

1.5 Ecosystem context

Primarily a central and southern European species, the species' range extends into the Caucasus, Anatolia and Morocco, to southern Sweden and south-east Norway, north Wales and eastern England (Lincolnshire). A population on the Canary Islands is at present regarded as the endemic subspecies *B. barbastellus guanchae* (Trujillo and others 2002; Juste and others 2003). Although widely distributed, the species' range is highly fragmented, probably reflecting the scarcity of mature forest habitats with which barbastelles are most strongly associated (Mitchell-Jones and others 1999; Russo and others 2004; Zeale 2011; Rebelo and others 2012). Typically, barbastelles occur in low density and numbers and are generally considered to be rare or uncommon throughout their range (Rydell & Bogdanowicz 1997).

In Britain, the range extends mainly over southern and central England and Wales. The distribution of barbastelles in the UK is limited mainly by low summer temperatures and the availability of suitable woodland habitat (Appendix 1). They have a low probability of occurring in exposed upland habitats and built-up areas with relatively high light pollution (Appendix 1). Genomic analysis has confirmed that artificial lighting also negatively affects connectivity between barbastelle colonies across England, while broadleaf woodlands and riparian habitats facilitate gene flow between colonies (Razgour and others 2023). At the time of writing, at least 118 active maternity colonies are known in the UK; the most northerly is located in Lincolnshire (Davidson-Watts 2014). There is currently no evidence of migration or gene flow between English and European mainland populations (Rebelo and others 2012).

2. Units

2.1 Natural range and distribution

Square kilometres (km^2). This metric has been used in Article 17 reporting and for range estimations.

Counties where barbastelles have been recorded.

2.2 Population

Number of adult individuals.

2.3 Habitat for the species

Square kilometres (km^2). This metric has been used in Article 17 reporting and for range estimations.

3. Evidence

3.1 Current situation

Natural range and distribution

Barbastelles are recorded infrequently but regularly by acoustic detectors and maternity colonies are characterised as comprising a small number of adult females that collectively cover a large home range area, with evidence of territoriality among colony members and between neighbouring colonies (Greenaway 2008; Hillen and others 2009; Zeale and others 2012), indicating a widespread but sparse distribution. Records have increased considerably in recent years, largely due to improvements in, and more widespread use, of sensitive acoustic survey equipment capable of detecting the low-amplitude echolocation calls emitted by the species (Goerlitz and others 2010).

Matthews and others (2018) suggested a range of 67,610 km^2 in England and 74,189 km^2 in the UK. This estimate is the area enclosed by an alpha hull – the minimum size shape to enclose a set of points – encompassing presence data collected between 1995 and 2016. This method assumes all areas within the geographic range are suitable for the species (Figure 1).

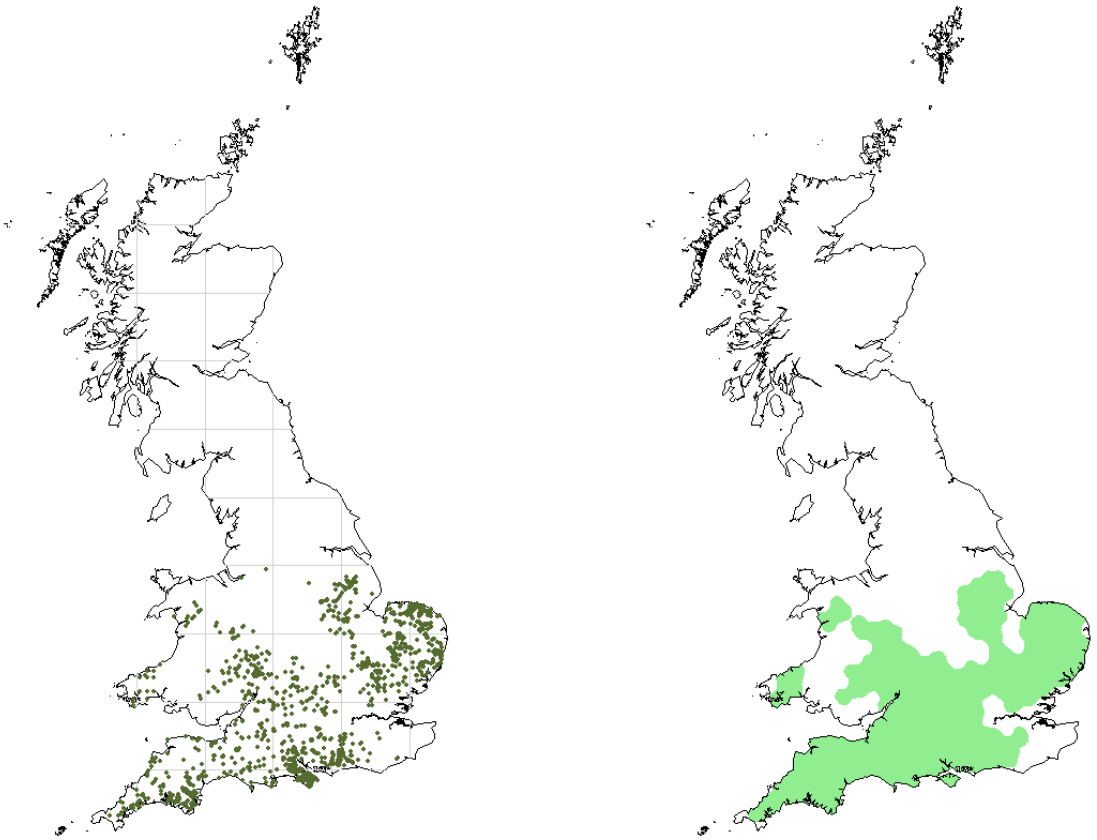

Figure 1 Left: Presence data collected between 1995 and 2016. Right: Smoothed alpha hull of presence records. Areas that contain very isolated records may not have been included

in the area of distribution (from Matthews and others 2018, reproduced under the Open Government Licence).

As described in Appendix 1, Zeale (2022) used a machine-learning method (MaxEnt) to model habitat suitability incorporating presence data collected between 1991 and 2021 and ten environmental variables relevant to barbastelles including summer temperature, landcover, and light pollution. A presence-absence prediction based on a thresholding method was used to estimate a range of 67,909 km^2 in England and 76,196 km^2 in the UK.

While these two estimates are remarkably similar, Zeale's estimate does not assume that all areas within the species' range are suitable and predicts a slightly wider but more fragmented distribution than that suggested by Matthews and others (2018) (Figure 2). Areas predicted to be unsuitable within the species geographic range are primarily areas of very low woodland density, built up areas with relatively high light pollution, and exposed upland habitats. The range is restricted in the north of England primarily by low summer temperatures (Appendix 1).

The species has been recorded in the following counties in England: Bedfordshire; Berkshire; Buckinghamshire; Cambridgeshire; Cornwall; Derbyshire; Devon; Dorset; Essex; Gloucestershire; Hampshire; Herefordshire; Hertfordshire; Isle of Wight; Kent; Leicestershire; Lincolnshire; Norfolk; Northamptonshire; Nottinghamshire; Oxfordshire; Rutland; Shropshire; Somerset; Suffolk; Surrey; Sussex; Warwickshire; Wiltshire; Worcestershire.

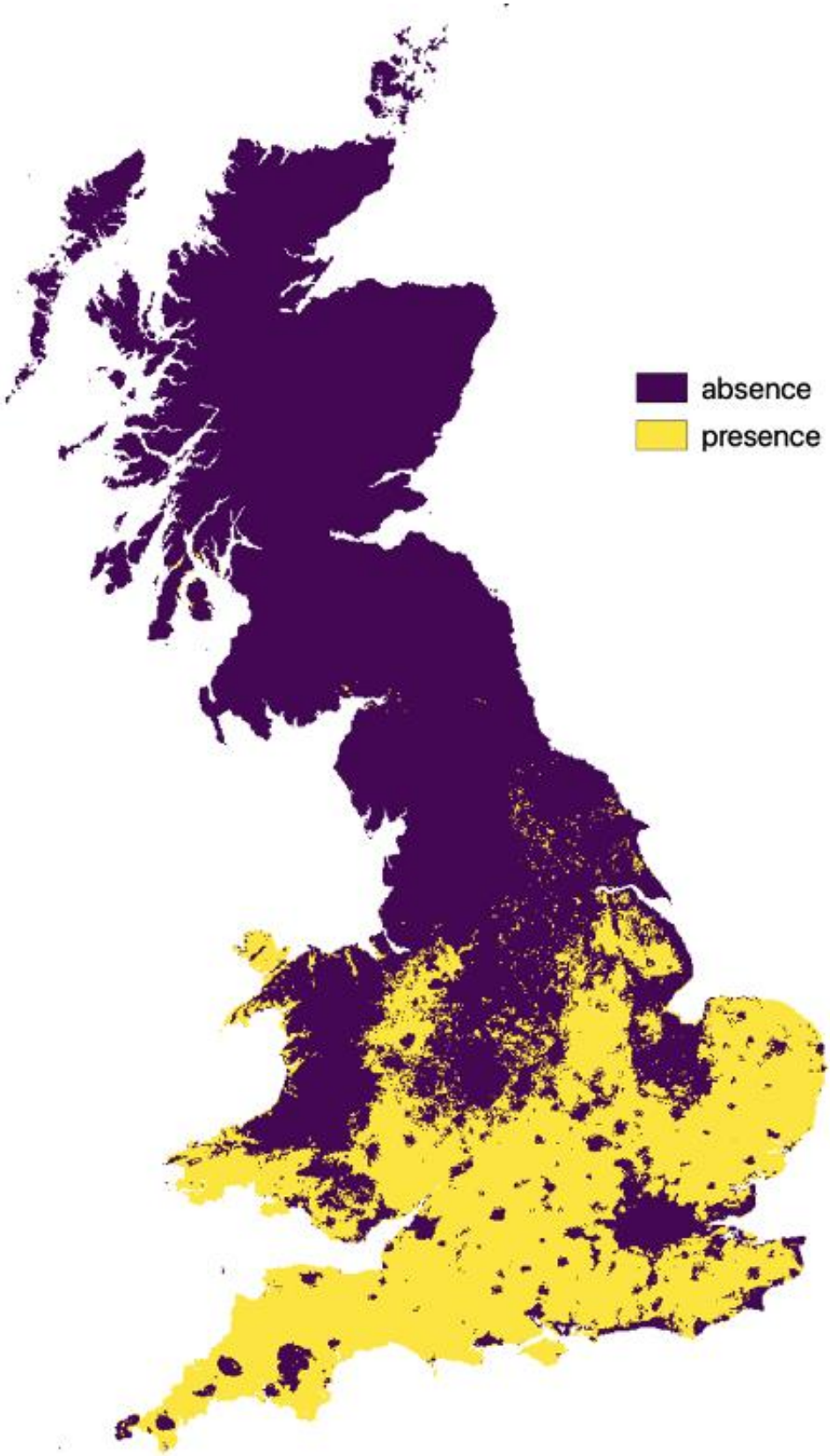

Figure 2 Predicted geographic distribution of barbastelle based on habitat suitability modelling (Appendix 1).

Confidence: Moderate

Population

At the time of writing, 108 maternity colonies are known in England and a further ten maternity colonies are known in Wales. There are undoubtedly many more colonies as yet undiscovered as those that have been identified to date are predominantly clustered in regions where there has been coordinated and targeted survey effort to discover new populations, typically involving radio-tracking methods.

The British population is split between midlands-north and south population clusters. The sampled populations were in Bedfordshire, Warwickshire, Nottinghamshire and Sussex and Devon respectively. The two populations are estimated to have split more than 8,000 years ago, after the post-glacial colonisation of Britain, though there is ongoing gene flow between them (Razgour and others 2023).

As described in Appendix 1, using a machine learning method (MaxEnt) to model (i) the species' geographic distribution in the UK, and (ii) the availability of suitable woodland roosting habitat for maternity colonies (using the 118 known colonies described above to train the model), Zeale (2022) estimated that there may be up to 524 colonies in England and 587 colonies in the UK. Assuming an average of 20-40 adult female bats within a single maternity colony and an adult sex ratio of 1:1, the total adult population of barbastelles was estimated to be in the region of 21,000-42,000 bats in England and 23,500-47,000 bats in the UK. However, it was noted that these figures are highly speculative as they are based on relatively coarse models and broad assumptions regarding occupancy rates, sex ratios and colony size. Indeed, Matthews and others (2018) state that due to a lack of information on the sex ratio of the UK population, the density of maternity roosts and the occupancy of woodlands of different structure or in different regions, as well as the propensity of colonies to fragment frequently such that a single colony may occupy multiple tree roosts at one time, it is particularly challenging to derive a population estimate for this species. They concluded that no estimate of population size could be given. Therefore, as such, these figures provide only an estimate of what the population size may be and they should not be interpreted as the actual size of the population (Appendix 1).

Confidence: Low

Habitat for the species

There are a few estimates of the extent of supporting habitat for barbastelles. However, these are all approximations of the extent of habitat suitable for barbastelles and all the figures should be treated with caution.

The area of supporting habitat for the barbastelle was estimated as 23,800 km^2 for England and 25,590 km^2 for the UK in the 3rd UK Habitats Directive Report (JNCC 2013). However, within the 4th Habitats Directive Report it was determined that there is insufficient information available to make a reliable assessment (JNCC 2019). It is not

known whether the amount of habitat in England or the UK is sufficient for the species' long-term survival (JNCC 2019).

Defining habitable area as all broadleaved woodland within the species range, Matthews and others (2018) calculated the total habitable area to be 6,100 km^2. However, the total area of suitable habitat will include other habitats selected by the species when roosting and foraging and so the true habitat area will be larger.

As described in Appendix 1, Zeale (2022) calculated the area of supporting habitat for the species by determining the distribution and extent of habitats known to be preferred by barbastelles for roosting and foraging. Supporting habitat was mapped to a high spatial resolution and included the following habitat types: broadleaved woodland, mixed woodland, woody linear features (hedgerows and treelines), riparian vegetation (bankside vegetation within a 10 m buffer area along rivers, streams and canals), semi-improved grassland (calcareous and neutral grassland) and freshwater wetland habitats (including fen, marsh and swamp). The area of habitat was calculated to be 17,190 km^2 in England and 20,419 km^2 in the UK. Within the species' predicted geographic distribution (determined by species distribution modelling), the area of supporting habitat was estimated to be 10,435 km^2 in England and 12,195 km^2 in the UK. However, it should be noted that this is only an estimate of the habitat available and there may be other environmental or anthropogenic factors that mean the habitat is not suitable for barbastelles.

Confidence: Moderate

3.2 Historical variation in the above parameters

Natural range and distribution

The current estimated range is similar to that indicated by available historical data, with the exception that there are no longer any records from north of the Humber. The considerable increase in records in England and Wales over the last two decades has not increased the range demonstrably beyond that described by Arnold (1993).

The estimated range reported in the most recent Article 17 Report (JNCC 2019) is slightly smaller than that reported in the previous Report (JNCC 2013), however this is due to methodological differences and does not represent a real reduction in range.

Population

There are currently no confident measures of population size, and there are very few records for this species prior to 1993 (Arnold 1993), which has made it difficult to determine whether population size has changed over time.

An earlier estimate of 5,000 individuals across England (4,500) and Wales (500) was suggested by Harris and others (1995), but this was based on subjective estimates of

relative abundance as there were few density estimates and a paucity of quantified data on bat numbers in relation to habitat associations and patterns of land use. The estimate was believed on subjective criteria to be within the right order of magnitude, but no greater degree of accuracy was thought to have been achieved (JNCC 2013).

Razgour and others (2023), however, have used a genomic approach to estimate historic population levels and changes in population size. They find that both the northern and southern populations of barbastelle in England have declined by 99% in the past few hundred years. In the north, this loss has occurred in the last 330 years (90% credibility intervals: 72-816 years ago), and in the south in the last 548 years (126-1066 years ago). Despite the severe declines, the populations have low levels of inbreeding and effective population size is likely still high enough to prevent substantial losses of genetic diversity.

Habitat for the species

There is considerable potential for the historical habitable area to have been greater than it is now given habitat changes through loss of woodland, agricultural intensification and built development over the past 500 years. However, detailed information about the habitable area used historically by barbastelles is unavailable, meaning it is not possible to determine whether the habitat area for this species has changed significantly.

Confidence: Low

3.3 The future for the species and its conservation

Barbastelles are not adapting well to anthropogenic changes in the environment. The species continues to exhibit a strong preference for roosting in old-growth broadleaved woodland where veteran and dead trees are numerous, and the availability of preferred roost features is high. Very few maternity roosts in buildings are known. In England, in 2022, only two were known, in Norfolk and Wiltshire. Occasionally, male and individual female bats are reported roosting in buildings (typically uninhabited barns or outbuildings), but this is relatively uncommon. As such, any loss of old-growth woodland is expected to increase pressure on current populations and is a major threat to the species. Given that just 2.5% of the UK is covered by ancient woodland, the availability of suitable woodland roosting habitat is likely to be the primary factor limiting the size and distribution of populations, and so any forestry management practices that continue to remove old, dead or dying trees, or limit the potential for the natural succession of these features, are expected to affect the species status significantly in the future. Although preferred roost features can and do develop on younger trees, such occurrences are relatively infrequent, so new woodlands are unlikely to provide sufficient natural roosting opportunities to support a colony of barbastelles for perhaps 50 years or more. Even in established woodlands where there has been a history of management activities that have resulted in the reduction of roosting opportunities, it may take at least 30 years of favourable management before use of the site by barbastelles increases significantly (Carr and others 2020). There is thus currently no known proven mitigation or compensation for loss of

barbastelle woodland roosting habitat over the short to medium term. There are some novel unproven techniques which are discussed further in section 3.4.

Further loss of suitable woodland roosting habitat, which cannot be readily replaced, mitigated or compensated for, will likely result in an increasingly fragmented and sparse distribution and greater risk of genetically isolated populations.In the short to medium term, bat boxes designed specifically for barbastelles will likely be beneficial for supporting existing colonies. Species-specific bat boxes have been used in woodlands where colonies are already established to provide additional roosting opportunities and, in some cases, these may be used in preference to more ephemeral natural roost features, such as defoliating bark (Greenaway 2008; Rachwald and others 2018).

The species appears to be sensitive to disturbance at roosting sites, with some maternity roosts in trees abandoned when approached by people during daylight hours (for example, Russo and others 2004). However, maternity colonies are also known in parklands and woodlands where there is regular human activity, and so sensitivity to disturbance is likely to be site-specific and bats probably habituate, to a certain extent, over time. In any case, increased anthropogenic disturbance at roost sites is likely to have a negative impact on populations, especially during the summer breeding period when females are rearing pups. The increasing human population in England and the continued loss of existing old-growth woodland will likely increase the level of human activity in remaining woodland habitats, placing populations of barbastelles at greater risk of disturbance.

The barbastelle is a light-shy species. Although observations of bats foraging at streetlights have been reported (Rydell and others 1996; Zing 1994), incidences are rare, and this behaviour has not been documented in England despite intensive study of numerous colonies in recent years. In general, the species avoids artificially lit areas and built-up habitats. In addition, genomic studies suggest artificial lighting and associated urban expansion also negatively affect connectivity and movement between colonies (Razgour and others 2023). In England, artificially lit areas are growing each year, both in radiance and extent, and increasingly spreading into the countryside from towns and cities. Today, approximately 80% of England has light-polluted skies at night. The trend towards increasing levels of light pollution in England, especially in rural environments, represents a considerable threat to light-shy bat species, in particular those with highly specialised diets comprised largely of insect taxa that exhibit strong positive phototaxis. As such, light pollution is expected to pose an increasing threat to barbastelle populations in England over the next 50-100 years by fragmenting habitats and reducing the availability of preferred moth prey in dark habitats.

Following emergence, barbastelles typically remain under the woodland canopy until dark. Once dark, however, bats regularly fly across open ground between roosting and foraging sites. Roads, motorways, and other clearings in natural vegetation do not appear to be a major barrier to movement or dispersal in the landscape and so probably do not restrict habitat accessibility to a significant extent (Kerth & Melber 2009). When roads and motorways are lit, however, barrier effects to movement may be substantially stronger.

Being specialist moth-feeders, barbastelles are especially vulnerable to declines in moth populations. Recent substantial declines in moths in England and throughout Europe are therefore cause for considerable concern with respect to future prospects for barbastelle populations (Conrad and others 2006; Fox 2013; Fox and others 2021).

Forest management practices, such as the use of synthetic pesticides to control insect pests, are thought to have contributed to enormous population decreases in barbastelles in eastern Europe in the 1950s to 1970s and ongoing use of pesticides in forestry poses a significant threat to the species. Similarly, agricultural operations that affect the biomass of preferred moth prey, such as the application of insecticides and fertiliser, drainage of wet habitats favoured by moths and other invertebrates, and removal of woodland habitat and field boundary features, such hedgerows and treelines, will have a considerable adverse effect on barbastelle populations in the future.

As is the case for all temperate bat species, climatic conditions are a critical factor in barbastelle survival and productivity and climate change is likely to have a significant impact on populations in the next 50-100 years. Models that take into account future changes in climate predict the climate niche for the barbastelle throughout its current European range will decrease substantially by 2100 (Rebelo and others 2010) with large areas of southern Europe becoming unsuitable. In England, the climate is expected to become more favourable for the species and parts of the north of England that are currently climatically unsuitable are likely to become increasingly more suitable, resulting in a potential range expansion into the north. However, English populations may not be adapted to warm and dry conditions experienced by the species in the Mediterranean and, therefore, there is also the potential for the species to decline within the current range. Under the more extreme scenarios of future climate change bats may struggle to adapt and survive in some parts of the range in the south of England, although this is highly speculative and needs further research. In addition, models predict an increase in bat species richness in the United Kingdom by 2100, as conditions become more favourable to species not currently resident. This could present a potential threat to barbastelle populations in England if it results in an increase in competition for roosting and foraging resources.

Natural range and distribution

The range of the barbastelle in England is limited mainly by low summer temperatures and the availability of suitable woodland roosting habitat (Appendix 1). Climate change could result in an increase in the species range in the north of England, although populations in the south may be negatively affected if they are not able to adapt to predicted warmer and drier conditions.

To increase resilience in the population to changing ecological circumstances, such as climate change, favourable conservation status requires an increase in the current range to include parts of the historic range. Determining the full extent of the species distribution within the current range through coordinated and systematic survey effort, particularly in

regions where few or no maternity colonies are known, will also be important to better understand the population structure in Great Britain and to identify isolated populations.

Modelling (see Appendix 1) indicates that barbastelles are predicted to be present in the following counties: Cheshire; South Yorkshire and Staffordshire and, with low probability, in East Riding of Yorkshire, North Yorkshire and West Yorkshire.

For favourable conservation status populations of barbastelle should be present across the species existing range and the six additional counties listed above.

Population

Low population density and slow population growth are likely to have made this species particularly vulnerable to factors such as loss and fragmentation of preferred woodland habitat. Colonies are comprised of few individuals (typically 20-40 adult females) and the relatively few maternity colonies that are known are sparsely distributed across a large geographic area. The lowest population estimate of 21,000 individuals in England and 23,500 individuals in the UK (Appendix 1) indicates that the current population may be larger than the minimum viable population, and genomic analysis indicates that the effective population size is likely high enough to prevent substantial losses of genetic diversity (Razgour and others 2023). However, as there is still considerable uncertainty in the size of the population, it is possible that the actual population could be sufficiently small to be vulnerable to the effects of inbreeding and stochastic events. There are likely many maternity colonies as yet undiscovered, and so locating new colonies should be a priority in order to determine occupancy in different woodland habitats and to enable a more reliable population estimate to be made.

There are large areas within the species' range where it has not been recorded, notably in central Wales and central England, raising concern that some populations may be isolated, although these gaps in the known distribution may be as a result of low survey effort in those areas, rather than an absence of the species.

A genomic study undertaken by Razgour and others (2023) indicated that both the northern and southern populations of barbastelle in England have declined by 99% in the past few hundred years, but despite this the populations have low levels of inbreeding. The causes of this decline are not known. It could have been brought about by natural causes, for example the climate cooling from the late medieval period to the end of the nineteenth century, or as a result of anthropogenic change, for example the move to plantation forestry, or a combination of these factors. Therefore, notwithstanding this information, the favourable population defined here will not directly seek to restore populations to those levels because they may not relate to a favourable population.

Instead, the favourable population is defined in relation to the favourable habitat within the favourable range. Zeale (Appendix 1) found that the potential number of maternity colonies that could be present in England within the species predicted geographic distribution was 1,638 colonies. Assuming an average of 20-40 adult females per colony and a sex ratio of

1:1, the total adult population of barbastelles could be 65,000–131,000 individuals in the current area of supporting habitat. However, favourable conservation status definitions for many habitats that comprise supporting habitat for barbastelles propose significant increases in extent and quality of those habitats. An increase in extent of approximately 12% is proposed for lowland mixed deciduous woodland in favourable conservation status (Natural England 2023), one of the lower increases in extent proposed. Therefore, the proposed favourable population has been increased by approximately 12% to 73,000-147,000 individuals to reflect the lower habitat increase proposed in a favourable situation.

Habitat for the species

The availability of dead and dying trees as roost sites and the lack of preferred foraging habitats, such as wetland, mature woodland and mature hedgerows, are major factors likely to affect the species status. Given the species exacting requirements, the main constraint to increasing current range and population levels is likely to be the availability of new suitable roosting opportunities.

Range expansion to the north for favourable status would have to be facilitated by roost availability and foraging habitat availability and, therefore, the habitat area required for favourable conservation status needs to increase. The proposal here is to increase in line with the increase proposed in the definition of favourable conservation status for lowland mixed deciduous woodland (Natural England 2023). As stated in the previous section, increases in many habitats supporting barbastelles are proposed for favourable conservation status with the increase in extent of lowland mixed deciduous woodland one of the lower figures. Therefore, the figure of approximately 12% represents the minimal area of habitat increase.

Zeale (Appendix 1) calculated the area of supporting habitat within the species predicted geographic distribution as 10,435 km^2 in England. Increasing this figure by 12% (the increase proposed for lowland mixed deciduous woodland) would give a figure of 11,700 km^2 in England (figure rounded). This figure is therefore taken as the minimum area of supporting habitat required for the species for favourable conservation status.

Confidence: Low

3.4 Constraints to expansion or restoration

Genomic research (Razgour and others 2023) has identified limiting factors in the expansion of this species in England as lack of availability of suitable broadleaf woodland and the incursion of artificial lighting that prevents landscape connectivity. Any expansion or restoration of the range in England would need to be facilitated by ensuring availability of suitable woodland roosting habitat and landscape connectivity that is not impacted by artificial lighting.

An increase in the number of maternity roosts would require a reversal in the loss of old-growth woodland and an increase in the availability of veteran and standing dead or decaying trees that develop preferred roost features. In addition, existing and potential roost sites should be protected from disturbance and development.

Restoration and creation of roosting habitat is technically feasible, although it may take decades of favourable management before significant increases in roosting opportunities develop naturally via woodland restoration. However, an increase in broadleaf woodland would greatly aid connectivity and foraging opportunities in the intervening period. The protection and restoration of old-growth woodland will be beneficial to a broad range of species in England.

In the short term novel techniques such as ring barking and ‘veteranisation’ of trees may help to increase roosting opportunities more quickly, however their effectiveness is currently unknown. Additionally in the short to medium term, bat boxes designed specifically for barbastelles will likely be beneficial for supporting existing colonies.

Given the species’ highly specialised diet, an increase in the population will need to be supported by efforts to restore moth populations around existing roost sites and new potential colonisation sites. Focus should be on restoring and increasing wetland and woodland habitats that support high moth biomass. Maintaining and improving hedgerows and treelines will also be beneficial, especially in landscapes where wetland and/or woodland is relatively scarce. These landscape-scale habitat improvements are technically feasible. The maintenance of a mosaic of natural habitats with good connectivity at the landscape scale will also be beneficial to many other species in England.

Within the current range, the distribution of colonies falls into northern and southern population clusters. Ideally priority needs to be given to providing conditions that ensure gene flow is maintained within each of the population clusters to ensure long-term evolutionary potential for the species.

Given the difficulty locating and monitoring colonies of barbastelles there may be many more colonies that are not currently known, or the average size of known colonies may be larger than currently estimated. As such, resources should be focussed towards identifying new colonies and obtaining reliable data on occupancy of different woodland habitats so that the species’ distribution can be more clearly defined, and a reliable estimate of population size made.

Confidence: Moderate

4. Conclusions

4.1 Favourable range and distribution

The favourable range and distribution is the current range and distribution plus populations in six additional counties (Cheshire, East Riding of Yorkshire, North Yorkshire, South Yorkshire, Staffordshire and West Yorkshire) where barbastelle are predicted to be present. Gaps in the species known distribution should be assessed by coordinated and focussed survey effort in suitable woodland roosting habitats to determine presence.

4.2 Favourable population

The current best estimate for the size of the population is between 21,000 and 42,000 individuals in England. As favourable conservation status requires restoration of the historic range, and a thriving situation, the favourable population is defined as 73,000-147,000 individuals within the favourable range and distribution. Further research and survey effort is required to identify new colonies and to improve understanding of the sex ratio and occupancy within different woodland habitats before a more reliable population estimate can be made.

4.3 Favourable supporting habitat

Within the species' favourable range and distribution the area of favourable supporting habitat is estimated to be 11,700 km^2 in England.

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Appendix 1: Modelling the geographic distribution and favourable supporting habitat for the barbastelle (*Barbastella barbastellus*) in Great Britain

Report to Natural England

Author: [redacted]

Introduction

The below modelling exercise was undertaken to (i) predict the geographic distribution of the barbastelle, *Barbastella barbastellus*, in Great Britain, (ii) estimate the area of favourable supporting habitat for the species in England and Wales, and (iii) predict the area of suitable woodland roosting habitat for *B. barbastellus* maternity colonies within the species' predicted geographic distribution to inform estimates of population size.

Methods

Modelling procedure

Two ecological niche models were developed to examine (i) the broad scale distribution of *B. barbastellus* in Great Britain (resolution 1 km^2), and (ii) the fine scale availability of suitable woodland roosting habitat for maternity colonies (resolution 50 m^2). Models were built using a presence-only (MaxEnt) approach (Phillips and others 2006), as determining absence of bats is extremely difficult and records of confirmed absences for *B. barbastellus* could not be sourced.

Broad spatial scale model

To model the species distribution in Great Britain, presence records for *B. barbastellus* were obtained from the National Biodiversity Network and the Global Biodiversity Information Facility and combined with records of confirmed maternity colonies obtained from ecologists, researchers and local bat groups. Only records from the past 30 years (1991-2021) were included to reflect current climatic conditions. To avoid pseudoreplication and to address sampling bias in the dataset, duplicate occurrence points were removed and a kernel density analysis performed on the remaining records to develop a bias file to inform sampling of background locations within Maxent. Models were built using ecogeographical variables deemed to be ecologically relevant based on prior knowledge of the biology and ecology of *B. barbastellus*. All variables had a spatial

resolution of 1 km^2. The following variables were included: spring, summer and winter temperature; temperature and precipitation seasonality; annual and summer precipitation; elevation (WorldClim); land cover (Land Cover Map 2020, Centre of Ecology and Hydrology, reclassified into ten classes); geology (British Geological Survey, reclassified into 18 classes); human population density (UK gridded population 2011); and night light pollution (National Oceanic and Atmospheric Administration).

Fine spatial scale model

To model the availability of suitable woodland roosting habitat for *B. barbastellus* maternity colonies, records of colonies (n = 118) were obtained from ecologists, researchers and bat groups across England and Wales. In most cases, colonies had been confirmed by radio-tracking of individual bats to tree roosts and subsequent dusk emergence surveys to confirm presence of multiple bats roosting together. In a few cases, evidence from trapping and acoustic surveys strongly indicated the presence of a colony (such as trapping of multiple breeding females and/or juvenile bats soon after sunset), albeit the presence of a colony had not been confirmed by radio-tracking. Models were built using ecogeographical variables that characterised woodland habitats and the availability of surrounding supporting habitat. All variables had a spatial resolution of 50 m in order to maintain reasonable definition of woodland boundaries. A description of the variables used in the model are provided in Table 1.

Table 1 Description of ecogeographical variables used in the fine-scale model (50 m resolution) to examine the availability of suitable woodland roosting habitat for *B. barbastellus* maternity colonies in Great Britain

Variable	Description
Woodland type	National Forestry Inventory dataset (Forestry Commission), reclassified into three classes: broadleaved woodland, mixed mainly broadleaved woodland, and conifer. Woodland classes that are likely to provide little or no roosting opportunities for *B. barbastellus* (such as young trees, coppice, scrub, and felled areas) were removed. The reclassified dataset was combined with the Ancient Woodland Inventory dataset (Natural England) and reclassified into five classes: ancient broadleaved woodland, broadleaved woodland, ancient mixed mainly broadleaved woodland, mixed mainly broadleaved woodland, and conifer. As none of the maternity colonies discovered to date are located within conifer woodland, all conifer types, including conifer plantation on ancient woodland sites (PAWS), were lumped together into a single 'conifer' habitat category to remove unnecessary complexity within the model, which can reduce predictive performance.
Density of roosting habitat	Using the 'woodland type' layer above, conifer woodland was removed from the dataset and the remaining four broadleaved woodland classes reclassified into a single broadleaved woodland class. Based on current evidence, conifer woodland provides negligible roosting opportunities for *B. barbastellus* while each of the broadleaved woodland categories all have potential for supporting barbastelle maternity colonies. The area of broadleaved woodland within 1 km radius of each 50 m grid cell was calculated. As the maximum distance between tree roosts used by a single colony typically does not exceed 1-2 km, an area of 1 km radius was considered appropriate for calculations of woodland density associated with roosting sites.

Variable	Description
Density of foraging habitat	Information from four separate datasets were combined, including Land Cover Map 2020 (Centre for Ecology and Hydrology (CEH)), National Forest Inventory (Forestry Commission), Woody Linear Features (CEH) and OS MasterMap Water Network (Ordnance Survey). The following habitats were extracted from these datasets and combined into a single 'foraging habitat' layer: broadleaved woodland; mixed woodland; woody linear features (hedgerows and treelines); riparian bankside vegetation within a 10 m buffer area along rivers, streams and canals; semi-improved grassland (calcareous and neutral grassland); and freshwater wetland habitats (including fen, marsh and swamp). These habitats are known to be significantly selected by *B. barbastellus* when foraging. These layers were initially mapped at a scale of 5 m resolution in order to preserve definition in linear landscape features (hedgerow, treelines, rivers and canals) and to enable accurate area calculations to be made. The area of foraging habitat within a 6 km radius around each 50 m model grid cell was calculated to provide a measure of density of foraging habitat within core sustenance zones (CSZ), recognised to be 6 km radius around roosts for *B. barbastellus*.
Light pollution	Information on night light pollution was obtained from the National Oceanic and Atmospheric Administration (NOAA) Version 4 DMSP-OLS Nighttime Lights Time Series dataset, rescaled to 50 m resolution.
Human population density	Data on human population density was obtained from the Environmental Data Information Centre UK Gridded Population 2011 dataset (based on Census 2011 records and Land Cover Map 2015), rescaled to 50 m resolution.

Model evaluation

Modelling procedures followed recommendations in Merow and others (2013) and Feng and others (2019), comparing several models with different variables and parameter combinations (regularisation values and number of features included) using the *ENMeval* package in R Studio (ver. 2021.09.0). Selection of the best performing model was based on Akaike information criterion (AIC) scores. For both the broad-scale and fine-scale model, the final full model included all features and a regularisation value of 1, 10 000 background points, and 1,000 iterations. Model performance was tested with ten-fold cross-validation and evaluated based on the Area Under the Curve (AUC) of the Receiver Operating Characteristics (ROC) curve, which measures the model probability of correctly distinguishing presence from random locations. Models with AUC scores higher than 0.8 are considered to have good to high model discrimination ability. Prior to model building, continuous ecogeographical variables were tested for multicollinearity using the *raster* package in R Studio and highly correlated ($R^2 > 0.8$) variables were removed, retaining the more ecologically relevant of the two correlated variables or the variables that contributed most to the model (Merow and others 2013; Razgour and others 2013; Feng and others 2019). For the broad-scale model, the model output was converted into a binary map of predicted presence-absence to illustrate the geographic distribution of *B. barbastellus* using the thresholding method that maximises the sum of sensitivity plus specificity (MSS) (Razgour and others 2013). For the fine fine-scale model, two thresholds were used. Woodland habitat with suitability scores above the MSS threshold were defined as suitable for maternity colonies, while locations with suitability scores between the zero-omission

and MMS thresholds were defined as marginally suitable. Woodland with a suitability score below the zero-omission threshold was considered unsuitable for *B. barbastellus* maternity colonies.

Supporting habitat

The area of favourable supporting habitat for *B. barbastellus* in England and Wales was calculated using information from four separate datasets: Land Cover Map 2020 (Centre for Ecology and Hydrology (CEH)); National Forest Inventory (Forestry Commission); Woody Linear Features (CEH); and OS MasterMap Water Network (Ordnance Survey). The following habitats were extracted from these datasets and combined into a single layer: broadleaved woodland; mixed woodland; woody linear features (hedgerows and treelines); riparian vegetation (bankside vegetation within a 10 m buffer area along rivers, streams and canals); semi-improved grassland (calcareous and neutral grassland); and freshwater wetland habitats (including fen, marsh and swamp). These habitats are known to be significantly selected by *B. barbastellus* when roosting and foraging (Sierro 1999, 2003; Sierro and Arlettaz 1997; Greenaway 2001; Hillen and others 2009; Zeale and others 2012) and were mapped at a scale of 5 m resolution in order to define linear landscape features accurately (hedgerow, treelines, rivers and canals) and to enable accurate area calculations of habitat to be made. The total area of supporting habitat was calculated throughout England and Wales, and also within the species' predicted geographic distribution (broad-scale model) within England and Wales.

Population estimates

The potential number of maternity colonies in England and Wales was estimated by determining the number of 5 km grid cells within the species predicted geographic distribution (broad-scale model; MSS threshold) that contain sufficient suitable woodland roosting habitat to support a colony (fine-scale model; MSS threshold), and assuming that only one colony may occupy one 5 km cell (reflecting the species' CSZ and evidence that colony home ranges do not overlap). This represents the potential maximum number of colonies that may be present. A more conservative estimate was made by calculating the ratio of known colonies to potential colonies (suitable 5 km grid cells) in areas where considerable focussed survey work has been undertaken and subsequently adjusting the potential maximum number of colonies in England and Wales by this ratio. The assumption is made that all colonies in these focussed areas have been discovered.

Results

Broad-scale habitat suitability model

The model had a good fit (mean AUCtest = 0.838). The model output and the predicted species geographic distribution are presented in Figure 1. Ten ecogeographical variables were included in the final model, however three variables (summer temperature, landcover, and light pollution) contributed a combined 88% of the model performance. The

most informative variable on its own was summer temperature, whereas the variable containing the most unique information was landcover (Figure 2). Based on the model predictions, *B. barbastellus* has a high probability of occurring in woodland areas at lower elevations with relatively higher summer temperatures, lower light pollution, higher winter temperatures, lower summer rainfall, and lower seasonal variation in rainfall. The species has a low probability of occurring in exposed upland habitats and built-up areas. The total area predicted to be suitable for *B. barbastellus* in Great Britain, and where the species is therefore predicted to be present, is 76,196 km^2. The total area predicted to be suitable in England is 67,909 km^2, and in Wales is 8,287 km^2. Individual counties in England and Wales where the species is expected to be present according to the model predictions are shown in Table 2 and Table 3, respectively.

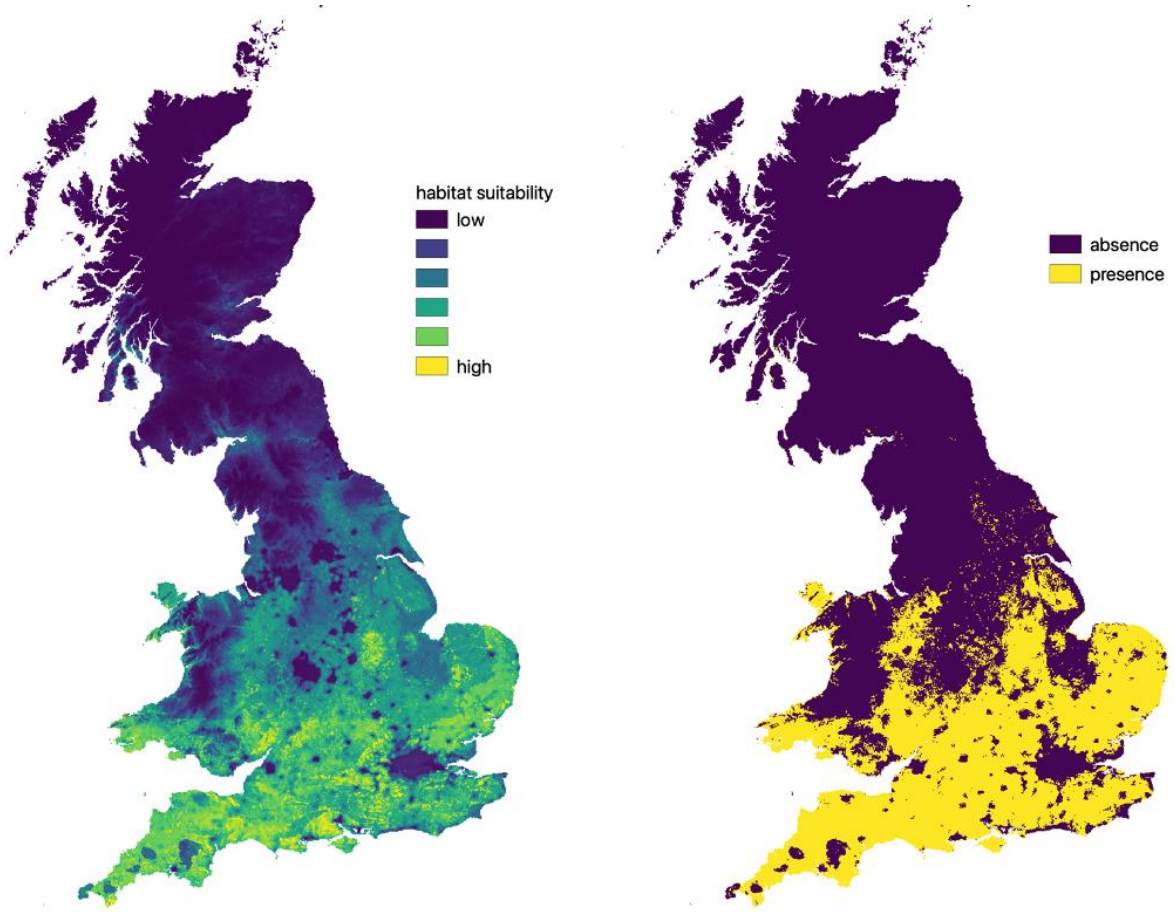


Figure 1 Predictions from the broad-scale model showing the model output of continuous environmental suitability for *B. barbastellus* in Great Britain (left) and the binary species presence-absence prediction (right) based on the thresholding method that maximises the sum of sensitivity plus specificity (MSS)

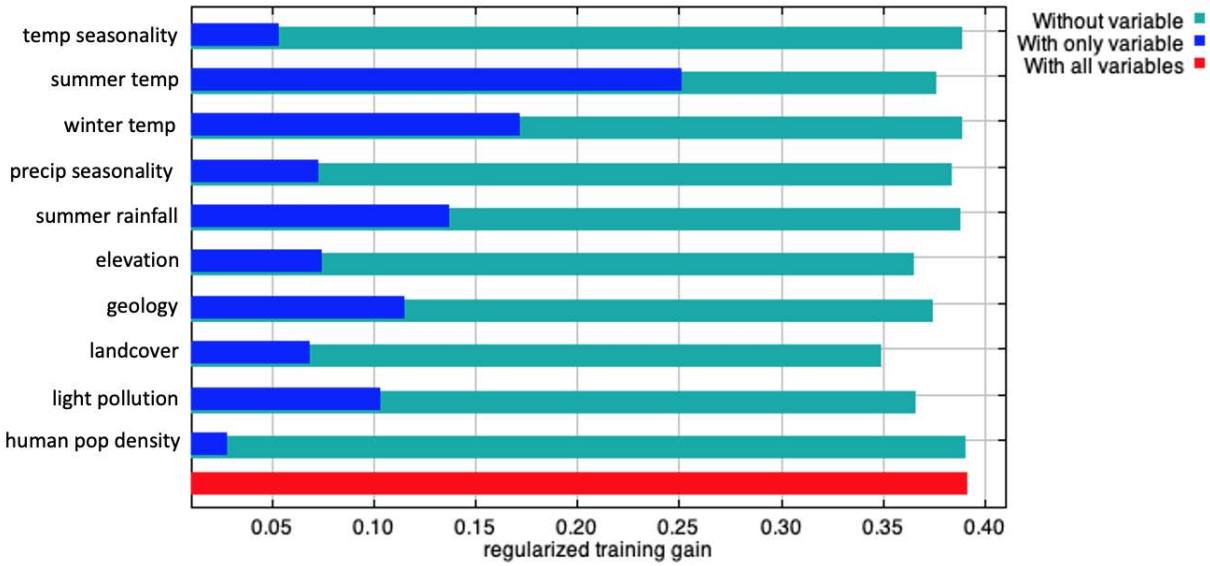


Figure 2 Jackknife of regularised training gain for *B. barbastellus* in Great Britain, listing variables included in the model and their relative contribution to the model in terms of increasing model gain when used in isolation (dark blue bars) and on decreasing model gain when omitted from the model (extent of reduction in light blue bars relative to red bar).

Table 2 Counties in England and where *B. barbastellus* (i) has already been recorded ('Confirmed present'), (ii) is predicted to be present by species distribution models but has not yet been recorded ('Predicted present'), and (iii) is predicted to be present but where models predict very few and/or sparse areas of suitability ('Predicted marginal'). Marginal counties are at the northern edge of the species range

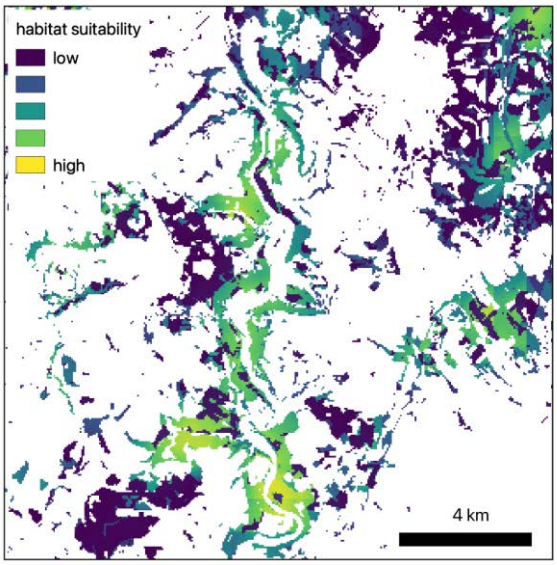
Confirmed present		
Bath and north-east Somerset	Hampshire	Rutland
Bedford	Herefordshire	Shropshire
Bournemouth, Christchurch and Poole	Hertfordshire	Somerset
Bracknell Forest	Isle of Wight	South Gloucestershire
Bristol, City of	Kent	Southampton
Buckinghamshire	Leicestershire	Suffolk
Cambridgeshire	Lincolnshire	Surrey
Central Bedfordshire	Milton Keynes	Swindon
Cornwall	Norfolk	Torbay
Derbyshire	North Somerset	Warwickshire
Devon	Northamptonshire	West Berkshire
Dorset	Nottinghamshire	West Sussex
East Sussex	Oxfordshire	Wiltshire
Essex	Peterborough	Windsor and Maidenhead
Gloucestershire	Plymouth	Wokingham
	Redbridge	Worcestershire
Predicted present		
Barnsley	North East Lincolnshire	Southend-on-Sea
Bromley	North Lincolnshire	Staffordshire
Cheshire East	Rutland	Telford and Wrekin
Cheshire West and Chester	Solihull	Thurrock
Medway		
Predicted marginal		
Doncaster	Leeds	Sheffield
East Riding of Yorkshire	North Yorkshire	Wakefield
Kirklees	Rotherham	Wirral

Table 3 Counties in Wales and where *B. barbastellus* (i) has already been recorded ('Confirmed present'), (ii) is predicted to be present by species distribution models but has not yest been recorded ('Predicted present'), and (iii) is predicted to be present but where models predict very few and/or sparse areas of suitability ('Predicted marginal'). Marginal counties are at the northern edge of the species range

Confirmed present		
Carmarthenshire Ceredigion Gwenydd Monmouthshire	Neath Port Talbot Pembrokeshire Powys	Rhondda Cynon Taf Swansea Vale of Glamorgan
Predicted present		
Blaenau Gwent Bridgend Caerphilly	Cardiff Merthyr Tydfil Newport	Torfaen Wrexham
Predicted marginal		
Conwy Denbighshire	Flintshire	Isle of Anglesey

Fine-scale habitat suitability model

The model had a good fit (mean AUC_{test} = 0.877). An example of the predictions made by the model are presented in Figure 3. The variable that contributed most to the model was woodland type (40%), followed by density of broadleaved woodland (36%), light pollution (18%), and availability of foraging habitat within 6 km core sustenance zones (6%). The contribution of human population density to the model was negligible (<1%). The most informative variable on its own was woodland type, whereas the variable containing the most unique information was density of broadleaved woodland (Figure 4). Based on the model predictions, *B. barbastellus* maternity colonies have a high probability of occurring in ancient broadleaved woodland within landscapes that are relatively dense with broadleaved woodland, have high availability of foraging habitat, and where light pollution and human population density are low.



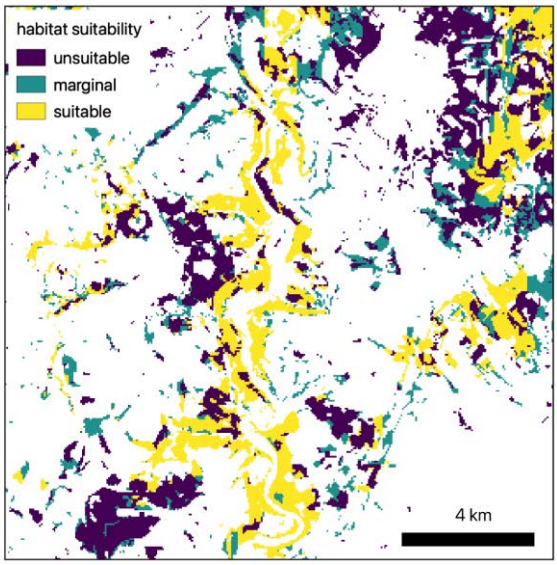


Figure 3 Predictions from the fine-scale model showing the model output of continuous suitability of woodland habitats for *B. barbastellus* maternity colonies (left) and the ternary prediction of suitability (right) showing suitable, marginal, and unsuitable woodland habitat based on zero omission and MSS thresholds

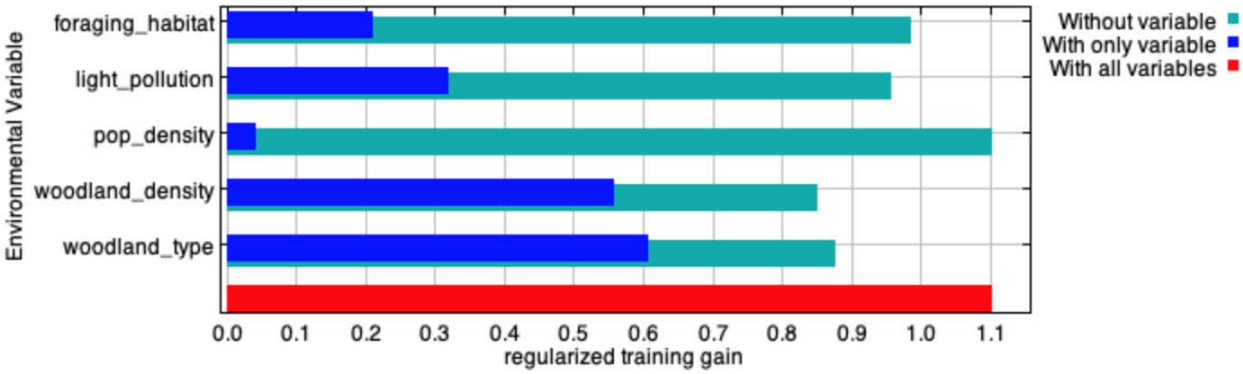


Figure 4 Jackknife of regularised training gain for model predicting suitability of woodland habitats for *B. barbastellus* maternity colonies in Great Britain, listing variables included in the model and their relative contribution to the model in terms of increasing model gain when used in isolation (dark blue bars) and on decreasing model gain when omitted from the model (extent of reduction in light blue bars relative to red bar).

Favourable supporting habitat

The area of favourable supporting habitat for *B. barbastellus* is estimated to be 17,190 km^2 in England and 3,229 km^2 in Wales (combined 20,419 km^2). Within the species' predicted geographic distribution (broad-scale model), the area of favourable supporting habitat is estimated to be 10,435 km^2 in England and 1,760 km^2 in Wales (combined 12,195 km^2).

Woodland roosting habitat

The area of suitable woodland roosting habitat for *B. barbastellus* maternity colonies is estimated to be 3,138 km^2 in England and 450 km^2 in Wales (combined 3,588 km^2). The area of marginal woodland roosting habitat is estimated to be 1,919 km^2 in England and 328 km^2 in Wales (combined 2,247 km^2). Within the species' predicted geographic distribution (broad-scale model), the area of suitable woodland roosting habitat for *B. barbastellus* maternity colonies is estimated to be 2,588 km^2 in England and 292 km^2 Wales (combined 2,880 km^2). The area of marginal woodland roosting habitat is estimated to be 1,455 km^2 in England and 185 km^2 in Wales (combined 1,640 km^2). It is important to note that these values are likely to be overestimates as it was not possible to include additional variables in the model that would reduce the area of predicted suitable woodland further, such as the availability of veteran or dead and decaying trees that are typically favoured by *B. barbastellus*, but which are relatively uncommon. UK-wide data for very fine scale variables such as these currently do not exist.

Planted ancient woodland

None of the maternity colonies discovered to date are located within conifer woodland. As such, within the fine-scale model all conifer types, including conifer plantation on ancient

woodland sites (PAWS), were lumped together into a single ‘conifer’ habitat category to remove unnecessary complexity in the model, which can reduce predictive performance. While conifer woodland is considered to be of negligible value as roosting habitat for *B. barbastellus*, there is potential for planted ancient woodland sites (PAWS) to be reverted to more suitable woodland habitats. The total area of conifer PAWS available in England and Wales is estimated to be 672 km^2 and 199 km^2, respectively. Within the species’ predicted geographic distribution (broad-scale model), the area of conifer PAWS is estimated to be 540 km^2 in England and 107 km^2 in Wales.

Population size

The potential number of colonies that may be present within the species predicted geographic distribution (broad-scale model) is estimated to be 1,834, comprising 1,638 colonies in England and 196 colonies in Wales. These are maximum values, based on the assumption that all potential colony sites (modelled 5 km grid cells) are occupied (Figure 5). However, within areas of England and Wales where considerable focussed survey work has been undertaken to locate maternity colonies, approximately one third (32 %) of potential colony sites are occupied by known colonies. As such, the total number of colonies is perhaps more likely to be 524 in England and 63 in Wales (combined 587 colonies). Assuming an average of 20-40 adult females per colony, it is estimated then that there may be between 10,483 and 20,966 breeding females in England and between 1,255 and 2,509 breeding females in Wales (combined 11,738 to 23,475 females). Assuming a sex ratio of 1:1, the total adult population of barbastelles may, therefore, be in the region of 21,000–42,00 individuals in England and 2,500–5,000 individuals in Wales (combined 23,500–47,000 individuals). It must be noted that these figures are highly speculative, based on relatively coarse models and broad assumptions regarding occupancy rates and colony size. As such, these figures provide only an estimate of what the population size of *B. barbastellus* may be. They should not be interpreted as the actual size of the population.

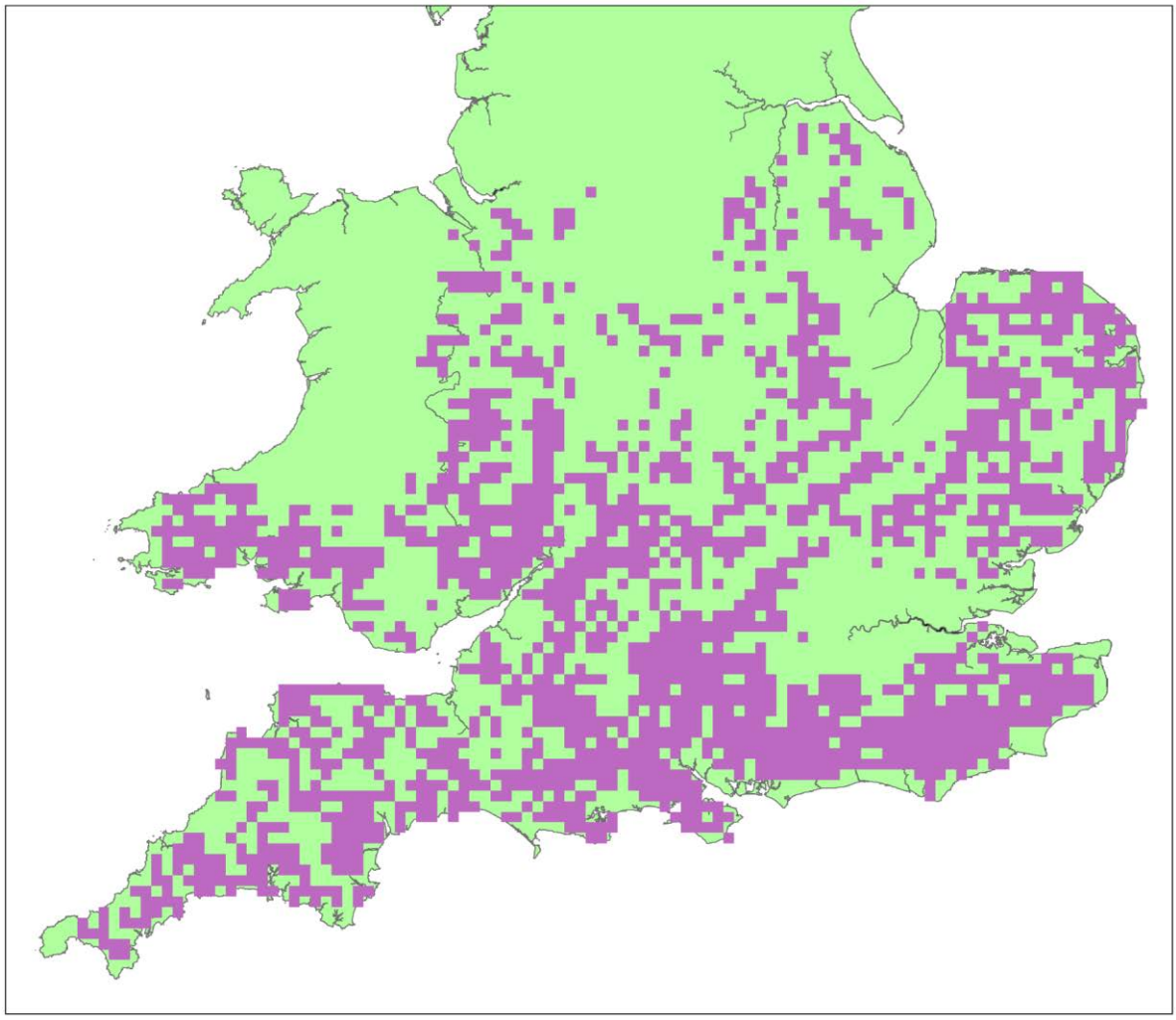


Figure 5 Distribution of 5 km grid squares (*n* = 1,834) predicted to contain sufficient suitable habitat to support a maternity colony of barbastelles (derived from fine-scale model); limited to within the species predicted geographic distribution in the UK (broad-scale model)

Limitations

The accuracy of predictions from ecological niche models are inherently constrained by the environmental datasets on which the models are built. There are now a large number of occurrence records for *B. barbastellus* in Great Britain, obtained predominantly as a result of increasingly widespread use of sensitive automated acoustic detectors, however knowledge of maternity colonies is still very limited (mainly because expensive and licensed advanced survey techniques are required to confirm the presence of colony roosts in woodland). Although the dataset of 118 colonies collected in this study represents a considerable increase in records in recent years, this is still a relatively low number of records on which to build an ecological niche model and there are large regions of England and Wales (within the species predicted geographic distribution) where no colonies have been discovered to date, most likely due to limited or no survey effort with advanced techniques in those regions. In addition, there are few environmental datasets currently available that can be used to define habitat characteristics at fine spatial scales.

For example, in this study it was not possible to include information on a number of factors that strongly influence the suitability of a woodland for *B. barbastellus* maternity colonies, such as tree species composition, availability of veteran or dead and decaying trees, and historical management of the site. Given these limitations, it should be noted that the predictions of the fine-scale model should be treated with caution, and the area of suitable roosting habitat for *B. barbastellus* maternity colonies predicted by this model is most likely an overestimate. In future, as increasingly sophisticated high-resolution environmental datasets become available, and as more colonies are discovered, models can be refined further, and the accuracy and robustness of model predictions can be improved.

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RESEARCH ARTICLE

Renewable energies and biodiversity: Impact of ground-mounted solar photovoltaic sites on bat activity

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Abstract

1. Renewable energy is growing at a rapid pace globally but as yet there has been little research on the effects of ground-mounted solar photovoltaic (PV) developments on bats, many species of which are threatened or protected.
2. We conducted a paired study at 19 ground-mounted solar PV developments in southwest England. We used static detectors to record bat echolocation calls from boundaries (i.e. hedgerows) and central locations (open areas) at fields with solar PV development, and simultaneously at matched sites without solar PV developments (control fields). We used generalised linear mixed-effect models to assess how solar PV developments and boundary habitat affected bat activity and species richness.
3. The activity of six of eight species/species groups analysed was negatively affected by solar PV panels, suggesting that loss and/or fragmentation of foraging/commuting habitat is caused by ground-mounted solar PV panels. *Pipistrellus pipistrellus* and *Nyctalus* spp. activity was lower at solar PV sites regardless of the habitat type considered. Negative impacts of solar PV panels at field boundaries were apparent for the activity of *Myotis* spp. and *Eptesicus serotinus*, and in open fields for *Pipistrellus pygmaeus* and *Plecotus* spp.
4. Bat species richness was greater along field boundaries compared with open fields, but there was no effect of solar PV panels on species richness.
5. *Policy implications*: Ground-mounted solar photovoltaic developments have a significant negative effect on bat activity, and should be considered in appropriate planning legislation and policy. Solar photovoltaic developments should be screened in Environmental Impact Assessments for ecological impacts, and appropriate mitigation (e.g. maintaining boundaries, planting vegetation to network with surrounding foraging habitat) and monitoring should be implemented to highlight potential negative effects.

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KEYWORDS
Chiroptera, echolocation calls, energy-wildlife conflict, environmental policy, farmland, green energy, photovoltaic panels, solar farm

1 | INTRODUCTION

Renewable energy is growing at a rapid pace globally, bolstered by almost all countries having renewable energy support policies in place (REN21, 2022). Renewable technology currently contributes an estimated 11% to global "total final energy consumption" with the potential to supply two thirds of total global energy demand, and Europe has the highest proportion of renewable energy and fastest growth in its use globally (Gielen et al., 2019; REN21, 2020; Singhal et al., 2015; Xu et al., 2019). Three technologies contribute the most capacity to global renewable power (3146 GW): hydro-electric (1195 GW 44%), wind (845 GW 25%) and solar photovoltaic (PV) (942 GW 24%), with solar PV increasing by 25% in 2021, the largest annual capacity increase recorded to date (REN21, 2022). The development of solar PV sites within the British rural landscape has grown over the last 10 years from virtually zero capacity in 2010 to over 13 GW capacity in 2020, with the majority of solar installations (92%) being <4 kW developments scattered throughout the landscape (Department for Business Energy and Industrial Strategy, 2021).

Renewable technologies are important in meeting energy demands sustainably, particularly with the associated benefits of favourable economics, low carbon footprints, ubiquitous resources, scalable technology and significant socio-economic benefits (Gielen et al., 2019). In the UK, solar PV has become recognised as the most popular renewable energy technology available to landowners due to opportunities for supporting environmental improvements, such as contributing to sustainable energy, while cutting business costs and providing substantial additional incomes through subsidies and ground rent (Chel & Kaushik, 2011; Jones et al., 2014; Mbzibain et al., 2013). In addition, the solar PV developments are temporary, with a 25–40 year life span, so once decommissioned the installation site can be restored to its original use almost immediately if necessary (Hernandez et al., 2014; Jones et al., 2014).

At present in Europe ground-mounted solar PV developments do not automatically trigger the scoping process for an Environmental Impact Assessment (EIA) (European Commission, 2021). The lack of formal assessment is a concern, as ground-mounted solar PV installation is permissible in undesignated ecologically sensitive areas (Gove et al., 2016). Conservation implications must, therefore, be given consideration when solar PV sites are in development, operation and during decommissioning to ensure any impacts are minimised and mitigated (Gibson et al., 2017). Renewable technologies such as hydro-electric and wind energy are already associated with detrimental effects on wildlife, leading to advice that improved policy and complex trade-off metrics are required to balance biodiversity impacts when planning for meeting energy demands (Holland et al., 2019; Kuvlesky Jr et al., 2007; Popescu et al., 2020). The need to balance wider impacts sparks a complex "green-green" dilemma, where the two desirable goals of clean energy and improved biodiversity have conflicting and potentially unresolvable effects on each other's success (Straka et al., 2020).

A well-considered and applicable decision support tool has been developed in the UK to assess Solar Park Impacts on Ecosystem Services but currently the focus of this is on localised ecological management for co-benefits rather than the initial appropriate and sensitive siting of developments within the ecological landscape (Randle-Boggis et al., 2020). Making this initial assessment is important to ensure that strategic decisions for land allocation align with energy policy (Popescu et al., 2020). This is particularly important as ground-mounted solar PV may have mixed to negative impacts on biodiversity.

On one hand, ground-mounted solar PV sites have the potential to positively influence biodiversity across the agricultural landscape where the existing land management does not consider ecology, and biodiversity is poor. For example, when properly sited, sensitively designed with biodiverse planting beneath and surrounding the panels, and carefully managed with ecological preservation in mind, the assigned land has the potential to develop a habitat network for pollinating species at a landscape scale and provide ecosystem services, including pest management to local crop production (Armstrong et al., 2021; Blaydes et al., 2021; Semeraro et al., 2018). This network approach could also make it possible to compensate for any cumulative and potentially detrimental impacts of developments near each other.

On the other hand, and despite the benefits of renewable energy in tackling energy demand and climate change, utility-scale solar PV developments are considered to potentially cause negative effects on biodiversity (Gielen et al., 2019). The alteration of land use, land cover, soils and water resources result in changes to microclimate and hydrological conditions, which have direct and indirect impacts on ecosystems (Hernandez et al., 2014; Pizzo, 2011). The resultant change can cause three key ecological effects: habitat loss and fragmentation, microclimate changes, and behavioural alterations, all of which may introduce barriers to relatively sedentary species by disrupting gene flow, while also reducing habitat availability for wide-ranging species which may disperse beyond the development sites (Hernandez et al., 2014; Pizzo, 2011), such as flying animals.

Bats are valuable bioindicators of change in ecological systems, as well as providing ecosystem services such as pest suppression, particularly in agricultural landscapes (Aguiar et al., 2021; Boyles et al., 2011; Jones et al., 2009; Kemp et al., 2019; Russo & Jones, 2015; Russo et al., 2018, 2021). This is in part due to their wide-ranging distributions and their position at the top of food chains, meaning they are affected by factors which have altered the prevalence of other

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species, such as habitat loss and fragmentation that may decrease the availability of invertebrate prey (Jones et al., 2009; Park, 2015; Russo & Jones, 2015). In the UK, 18 bat species comprise a third of all mammal species (Mathews et al., 2018). As such understanding the interactions of bats with solar PV installations is crucial in ensuring their protection, and to determine any effects on ecosystem health and services.

Parallels can be drawn between land development for solar PV and for wind turbines, especially in terms of habitat modification. Bats have been studied extensively in relation to wind energy, encompassing fatalities at turbines potentially caused by collision, flight paths affected by vortices, turbines being mistaken for roosts, used as mating sites and because insect prey can be attracted to turbines (Baerwald et al., 2008; Cryan, 2008; Cryan & Barclay, 2009; Cryan et al., 2014; Dahl et al., 2012; de Jong et al., 2021; Horn et al., 2008; Rydell et al., 2016; Voigt et al., 2022). Wind turbines also cause habitat loss due to bats avoiding surrounding wind turbines farms (Barré et al., 2018, 2022; Minderman et al., 2012, 2017). Successful mitigation has been developed accordingly, including curtailment and using acoustic deterrents (Adams et al., 2021; Arnett et al., 2013; Baerwald et al., 2009; Mitchell-Jones & Carlin, 2014; Weaver et al., 2020).

The potential implications of solar PV developments on bat species in Britain, as well as other wildlife, segments into direct and indirect impacts (Chock et al., 2021). A key potential direct impact is that bats may collide with solar panels, as bats perceive smooth, horizontal surfaces as water, and will approach such surfaces attempting to drink (Greif & Siemers, 2010; Greif et al., 2017; Russo et al., 2012). The indirect impacts of solar panels on bats may be subtler, with panels potentially increasing reflective temperature at night following a day of hot weather and also altering microclimate by blocking sunlight, rainfall and affecting drainage potentially reducing the availability of invertebrate prey (Froidevaux, Louboutin, et al., 2017; Horváth et al., 2010; Pizzo, 2011). In addition bats may actively avoid solar PV sites, as a consequence of habitat loss and fragmentation as solar energy can require large land footprints (Pang et al., 2014). A recent comparison of bat activity in solar farms and adjacent habitats in Hungary indicated that while some bat species may exploit solar farms others avoid them (Szabadi et al., 2023).

Despite the potential impacts solar PV sites could have on bats, there is no empirical evidence to inform their appropriate siting or informed mitigation because the effects of solar PV panels on bats have not been tested empirically yet. Thus, the aim of the study was to assess the potential impacts of ground-mounted solar PV sites on bat activity and bat species richness. More specifically, our objectives were to investigate species-specific bat activity and bat species richness in different habitats (field boundaries and open fields) within ground-mounted solar PV sites in the UK in simultaneous comparison with matched sites nearby that did not contain solar PV panels (control sites). Due to bats generally avoiding anthropogenic alterations, we predicted reduced activity and species richness at ground-mounted solar PV sites (Bender et al., 1998; Coleman & Barclay, 2013). We also predicted that bat species would be mainly affected at their foraging/commuting habitats, that is open space foragers will show reduced activity in fields containing solar PV panels, whereas species that utilise edge and cluttered habitats would be more affected along boundary habitats.

2 | MATERIALS AND METHODS

2.1 | Sampling design

We implemented a paired study design across 19 solar PV sites to assess whether bat species richness and activity were higher in fields and along boundary habitats that contained PV panels, compared with "empty", matched control sites. This resulted in 19 sampling points for solar boundary habitat, 19 for solar open habitat, 19 for control boundary habitat, and 19 for control open habitat. All sites were located in south-west England, where the highest concentration of solar PV sites and greatest bat species richness in the UK coincide (Department for Business Energy and Industrial Strategy, 2021; Mathews et al., 2018). Where private land was entered, permissions were granted by land owners and the relevant solar farm companies. No ethical approval was required for this study as we passively monitored bats through acoustic recordings.

The control sites were within the same land management boundary as the solar PV site, and matched as closely as possible in plot size, habitat type, land use and boundary habitats. There was no difference in the average size of solar PV and control fields (solar PV mean = 59.6 ha, SD = 32.0; control mean = 53.2 ha, SD = 28.4; paired *t*-test: $t(18) = 1.3$, $p = 0.203$) (see Appendix S3 in Supporting Information). All solar PV sites were on grassland that was either grazed or managed through mowing or were on cut arable crops. Field boundaries corresponded to hedgerows, treelines, woodland or vegetated ditches and were exactly matched. The paired fields were a minimum of 500 m apart and not adjacent to each other to maximise the chances of obtaining independent data within comparable landscapes (Froidevaux, Louboutin, et al., 2017).

2.2 | Bat echolocation call recording and species identification

Fieldwork was completed between July and October 2019 and the same period in 2020. Bat activity was monitored for seven consecutive nights at each site (30 min before sunset to 30 min after sunrise), simultaneously across the four locations (open and boundary habitats within the field with solar PV panels and paired control). Recordings were made using SM3 bat detectors (Wildlife Acoustics, Inc.). All detector microphones (SMM-U2f [frequency response +/− 6 dB 20–100 kHz see https://www.wildcare.co.uk/amfile/file/download/file/56/product/94208/], Wildlife Acoustics) were elevated to 1.27 m using identical tripods. Detectors were set to auto trigger between 8–120 kHz and 1–88 dB and recorded for a maximum of 10 s (384 kHz, sampling

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rate). A detector was placed within the centre of the control and solar fields, and along the associated boundary habitats of the control and solar fields. Detectors recording the open and boundary habitat within the solar and control field were a minimum of 50 m apart.

Sampling took place during optimal weather condition for bats to forage (i.e. no rain, low wind speed and temperature >10°C). The mean (±SD) temperature at dusk over the recording period was 16.2 ± 3.1°C (https://www.timeanddate.com/weather/).

Sound files were analysed using zero crossing software Kaleidoscope Pro (v. 5.4.1, Wildlife Acoustics, Inc.) with Bats of Europe Classifiers (United Kingdom) (v. 5.4.0) selected. All 10 s recordings were automatically scanned and the call sequences were identified and then manually checked to confirm the species (*Barbastella barbastellus*, *Eptesicus serotinus*, *Pipistrellus nathusii*, *P. pipistrellus*, *P. pygmaeus*, *Rhinolophus ferrumequinum* and *R. hipposideros*) or species group (*Nyctalus* spp., *Myotis* spp., *Plecotus* spp.). The grouping of *Myotis* spp. is widely used due to the difficulty of separating the echolocation calls of the different species (Russ, 2012). Similarly *Nyctalus noctula* and *N. leisleri*, as well as *Plecotus auritus* and *P. austriacus* could not always be separated so these calls were grouped as *Nyctalus* spp. and *Plecotus* spp., respectively. All files which Kaleidoscope Pro could not automatically assign a species to were identified manually (Russ, 2012).

All files which Kaleidoscope Pro classified as "Noise" (195,375 files) were run through the full spectrum software Bat Classify (https://bitbucket.org/chrisscott/batclassify/src/master/). This was to ensure no call sequences within the large number of "Noise" labelled files were missed. Following analysis, 0.5% of labelled files were randomly checked to ensure that the automated identification was reliable (Rowse et al., 2018). For all call sequences with >80% certainty in the automated identification, the classification to species was accepted, except for *Myotis* species where >50% certainty was accepted to ensure call sequences were not excluded from the dataset. These parameters were designed to apply a precautionary approach based on the Precision-Recall metric of the Bat Classify software (https://bitbucket.org/chrisscott/batclassify/src/master/).

2.3 | Statistical analysis

All analyses were performed in R statistical software v.4.1.1 (R Core Team, 2021) and all statistical tests were considered significant at $p < 0.05$. We performed generalised linear mixed-effect models (GLMMs) with "GLMMTMB" package (Brooks et al., 2017) to assess the effects of PV panels on species-specific bat activity and bat species richness in agricultural landscapes. Echolocation call sequence data were pooled by site and location over the seven-night period, and we defined bat activity as total number of bat call sequences for species or species groups. Due to their low occurrences (<40% of the sites), *R. hipposideros* and *P. nathusii* were disregarded for the analysis on species-specific activity. GLMMs on bat species were fitted with a Gaussian distribution (since diagnostic plots were largely unsatisfactory with Poisson or negative binomial distributions) and we applied a squared transformation to the response variable to meet the normality assumption. GLMMs on bat activity were fitted with a negative binomial distribution and we employed zero-inflated models when necessary. We included the presence/absence of PV panels (treatment: solar vs. control site) in interaction with the habitat type surveyed (boundary vs. open field) as explanatory variables while pair ID were considered as random factors to account for the paired-sampling design.

We also included in the models landscape variables that could potentially affect bat activity in agricultural landscapes, including the proportion of urban, arable land, grassland and broadleaf woodland, and the Euclidean distance to the nearest watercourse. For area-based landscape variables, we considered eight spatial scales (buffers ranging from 250 m to 10 km radii) to qualify local habitats around each site, and to encompass the wide foraging ranges of the bat species studied (Laforge et al., 2021). Landscape variables were derived in QGIS using the Land Cover Map (Environmental Information Data Centre, 2019) (20 m resolution) supplied by the Centre of Ecology and Hydrology. When comparing solar PV sites with control sites no statistical differences occurred in the distance to the nearest water source, or in cover of arable land, grassland, broadleaved woodland or urban areas at the different spatial scales with the exception of cover of grassland and arable habitat surrounding the control and solar PV site at the 250 and 500 m scales (Appendix S2). To reduce the number of landscape variables and avoid model overparameterisation, we assessed independently the relationships between the response variables and each landscape variable using GLMMs with the same model structure as described above (i.e. including the same random effect and the interaction and using the same distribution family). We compared the second-order Akaike information criterion (*AICc*) of each model with the model that included the interaction only and retained in the final models only landscape variables at their best scale of effect (Martin, 2018) that led to lower *AICc* (i.e. $\Delta AICc \geq 2$) (Burnham & Anderson, 2002). For highly correlated variables (Spearman coefficient correlation $|r| > 0.7$), we retained the one leading to lower *AICc*. From the final full models, we finally ran post hoc pairwise comparisons corrected for multiple testing using the Tukey method in the "LSMEANS" package (Lenth, 2014). Residual diagnostics were checked with the "DHARMA" package (Hartig, 2022). We also checked for multicollinearity, overdispersion, influential outlier and zero inflation with the "PERFORMANCE" package (Lüdecke et al., 2023).

3 | RESULTS

3.1 | Bat acoustic sampling

A total of 133 nights of recording took place simultaneously on each of the four bat detectors across 19 different sites, resulting in 532 individual nights of recording. This produced a total of 51,464 call

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sequences, comprising 10 species or species groups. The bat species most frequently recorded was *P. pipistrellus* (24,017 call sequences) with over twice the number of recordings of any other species or species group. The species most infrequently recorded were *P. nathusii* and *R. hipposideros* (106 and 170 call sequences, respectively). All species or species groups were recorded at each of the treatments (solar vs. control site) and habitat features (boundary vs. open field) (Table 1).

3.2 | Effect of solar PV panels on the activity of bats

Overall, we recorded more bat activity at the control sites than the solar PV sites, and more bat activity at the boundary habitats compared to the open field (Table 1). We found statistical evidence that the activity of six of eight species/species groups (i.e. *E. serotinus*, *Myotis* spp., *Nyctalus* spp., *P. pipistrellus*, *P. pygmaeus* and *Plecotus* spp.) were negatively affected by solar PV panels (Table 2 and Figure 1). For all these taxa, our full models on bat activity that included the presence/absence of solar PV site in interaction with the habitat type were more informative than the null one ($\Delta AICc > 2$; Appendix S1 in Supporting Information).

The effects of solar PV panels on bat activity were largely dependent on the habitat type investigated. Only *P. pipistrellus* and *Nyctalus* spp. were significantly, negatively affected by solar PV panels regardless of the habitat type considered. For other taxa, our models indicated a significant negative effect of solar PV sites on *Myotis* spp. and *E. serotinus* along the boundary habitats at the solar sites compared to control ones while *P. pygmaeus* and *Plecotus* spp. were significantly less active in the open habitat at solar sites compared to control ones (Table 2 and Figure 1). Finally, we found no difference in bat species richness between habitats at the solar sites and matched control ones.

3.3 | Effect of habitat type and landscape variables on the activity of bats

Regardless of the presence/absence of solar panels, all species/species groups (except *Nyctalus* spp. and *Plecotus* spp.) were significantly more active along field boundaries compared with open fields ($p < 0.05$). Similarly, there was greater bat species richness at field boundaries compared with open fields (See Appendix S1).

Arable land cover at the largest scale (10 km) positively influenced *B. barbastellus* activity and urban area at the largest scale had a positive effect on *P. pipistrellus* (See Appendix S2 in Supporting Information). Grassland cover had a significant positive effect on *E. serotinus* activity (500 m radius scale) and *Nyctalus* spp. activity (1 km radius scale). The number of species recorded was greater on farms located near freshwater sites.

4 | DISCUSSION

Our predictions regarding bat activity were largely supported, though species-specific differences were apparent. For several species, there was lower activity in fields with solar PV panels, in both open and boundary habitats, compared to matched fields without solar PV panels. Specifically, solar PV sites had a

TABLE 1 The number of bat call sequences recorded at boundary and open habitats at matched control and solar photovoltaic (PV) sites. Totals are for seven consecutive nights of recording at 19 habitat replicates in each column. [Correction added on 23-Aug, after first online publication: The values for "*Myotis spp.*" have been updated in this version.]

Species	Control, boundary	Solar PV, boundary	Control, open	Solar PV, open	Total
Barbastella barbastellus	314 (2.36 ± 3.6)	437 (3.29 ± 6.3)	31 (0.23 ± 0.6)	28 (0.21 ± 0.52)	810 (1.52 ± 3.88)
Eptesicus serotinus	1569 (11.8 ± 34.8)	457 (3.44 ± 12.31)	316 (2.38 ± 4.53)	155 (1.17 ± 3.73)	2497 (4.69 ± 19.1)
Myotis spp.	5816 (43.73 ± 103.92)	2529 (19.02 ± 39.85)	915 (6.88 ± 15.26)	755 (5.68 ± 6.68)	10015 (18.83 ± 58.16)
Nyctalus spp.	1283 (9.65 ± 13.65)	899 (6.76 ± 9.56)	1463 (11 ± 15.14)	773 (5.81 ± 7.24)	4418 (8.3 ± 11.98)
Pipistrellus nathusii	29 (0.22 ± 1.13)	25 (0.19 ± 0.95)	37 (0.28 ± 0.93)	15 (0.11 ± 0.81)	106 (0.2 ± 0.96)
Pipistrellus pipistrellus	11,855 (89.14 ± 163.04)	7156 (53.8 ± 121.64)	4404 (33.11 ± 96.48)	602 (4.53 ± 5.46)	24,017 (45.14 ± 116.45)
Pipistrellus pygmaeus	4176 (31.4 ± 138.77)	1219 (9.17 ± 16.65)	781 (5.87 ± 12.64)	250 (1.88 ± 5.48)	6426 (12.08 ± 70.96)
Plecotus spp.	472 (3.55 ± 4.4)	462 (3.47 ± 8.07)	941 (7.08 ± 13.13)	265 (1.99 ± 2.25)	2140 (4.02 ± 8.28)
Rhinolophus ferrumequinum	182 (1.37 ± 3.51)	565 (4.25 ± 16.84)	38 (0.29 ± 0.78)	80 (0.6 ± 2.52)	865 (1.63 ± 8.82)
Rhinolophus hipposideros	100 (0.75 ± 2.13)	62 (0.47 ± 1.24)	3 (0.02 ± 0.15)	5 (0.04 ± 0.23)	170 (0.32 ± 1.27)
Total	25,796 (193.95 ± 327.67)	13,811 (103.84 ± 160)	8929 (67.14 ± 120.64)	2928 (22.02 ± 19.31)	51,464 (96.74 ± 201.9)

Means ± SDs of bat passes/night/site are presented in brackets after the totals, with 7 nights at each of 19 habitat replicate sites.

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TABLE 2 Results of the post hoc pairwise comparisons applied to the GLMMs relating the effects of the presence/absence of solar photovoltaic panels (treatment: solar vs. control site) in interaction with habitat type (boundary vs. open field) on species-specific bat activity and bat species richness.

Dependent variable	Pairwise differences: Control versus solar	Est. & SE	*t* value	*p*
Species richness[a]	Boundary	−0.35 ± 4.82	−0.07	0.942
	Open	5.23 ± 4.82	1.09	0.282
Barbastella barbastellus activity	Boundary	0.06 ± 0.31	0.15	0.836
	Open	0.11 ± 0.41	0.26	0.795
Eptesicus serotinus activity	Boundary	1.23 ± 0.44	2.79	0.007**
	Open	0.74 ± 0.46	1.62	0.109
Myotis spp. activity	Boundary	0.69 ± 0.30	2.26	0.027*
	Open	0.14 ± 0.31	0.44	0.661
Nyctalus spp. activity[b]	Boundary	0.55 ± 0.22	2.54	0.013*
	Open	0.46 ± 0.21	2.19	0.032*
Pipistrellus pipistrellus activity	Boundary	0.80 ± 0.37	2.17	0.033*
	Open	1.31 ± 0.43	3.06	0.003**
Pipistrellus pygmaeus activity	Boundary	0.51 ± 0.42	1.21	0.232
	Open	0.93 ± 0.42	2.22	0.030*
Plecotus spp. activity	Boundary	0.23 ± 0.29	0.77	0.446
	Open	0.90 ± 0.30	3.02	0.004**
Rhinolophus ferrumequinum activity	Boundary	0.17 ± 0.60	0.28	0.782
	Open	0.81 ± 0.71	1.14	0.257

[a]Species richness was modelled using a Gaussian distribution. We applied a squared transformation to the response variable to meet the normality assumption.

[b]We employed a zero-inflated model to account for excess zeros in the response variable.

Est.: estimate, SE: standard error of the estimate. $^{**}p \leq 0.01$, $^{*}p \leq 0.05$, $p \leq 0.10$.

significant, negative effect on six out of the eight bat species and species groups analysed. *Eptesicus serotinus* and *Myotis* spp. had significantly lower activity along the boundary habitats at solar PV sites, compared to equivalent features at control sites. *Pipistrellus pygmaeus* and *Plecotus* spp. had significantly less call sequences recorded in the open habitat at solar PV sites compared with the centre of control fields. *Pipistrellus pipistrellus* and *Nyctalus* spp. were negatively affected by solar PV sites in both habitats (open and boundary habitats).

Hedgerows and connective features are important commuting and foraging features for bats (Froidevaux, Boughey, et al., 2017; Leroux et al., 2022). The significantly reduced numbers of *E. serotinus* and *Myotis* spp. along boundaries bordering PV solar sites suggests that the panels may be causing some bats to alter their flight paths, potentially resulting in further fragmentation of the ecological landscape. The reduced number of *P. pygmaeus* and *Plecotus* spp. in the open habitats suggests that solar PV is resulting in habitat loss for these species. *Nyctalus* spp. and *P. pipistrellus* were the only species found to be significantly affected at both open and boundary habitats.

We found that bat species that feed in both cluttered (some *Myotis* species) and edge habitats (*E. serotinus*) were affected along boundary habitats, and that species that feed in open space (*Nyctalus* spp.), cluttered (*Plecotus* spp.) and edge habitats (*P. pipistrellus*, *P. pygmaeus*) (Denzinger & Schnitzler, 2013) were negatively affected by the presence of solar panels in the open fields. *Barbastella barbastellus* and *R. ferrumequinum* activity did not differ between any of the sampling locations, which compliments results found in a similar study of solar farms. This may be due to the smaller sample size for these species providing low statistical power, their foraging strategies meaning the sampling habitat was not favourable, or because the panels where inconsequential for these species. The impacts of solar PV on bat activity are therefore best assessed on a species-specific basis, rather than trying to pool risk categories as has sometimes been done for other renewable energy technologies such as wind farms (Scottish Natural Heritage et al., 2021).

Our findings share some similarities with a recent study from Hungary (Szabadi et al., 2023), where *P. pygmaeus* (compared with open grasslands) and *Myotis* spp. (compared with both open

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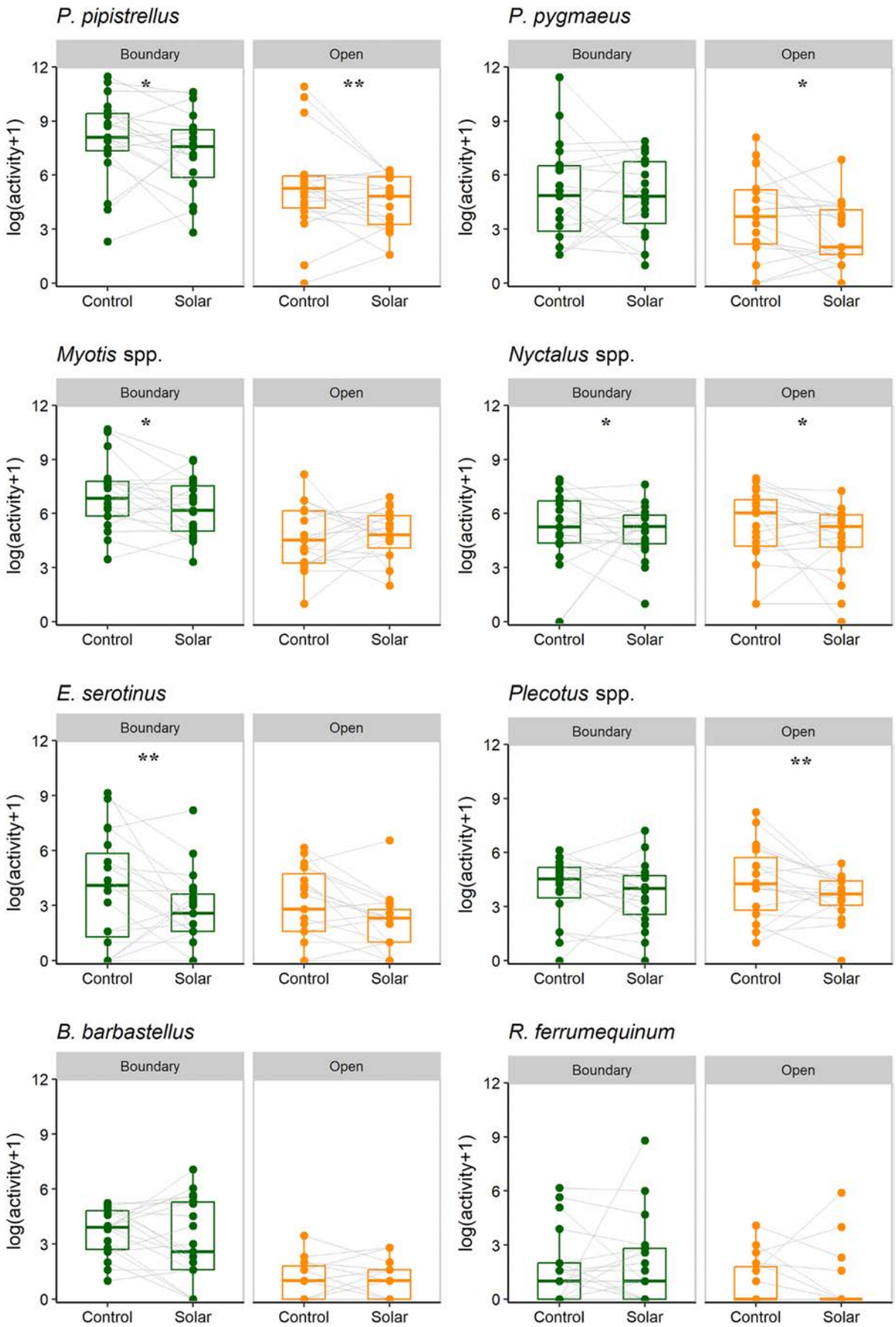

FIGURE 1 Boxplots showing medians and interquartile ranges of species-specific bat activity (i.e. total number of bat call sequences per site on a logarithmic scale to the base 2) at control and solar PV sites. Dots represent raw data with paired sites linked with a grey line. $^{**}p<0.01$ and $^{*}p<0.05$.

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grassland and forest) showed lower activity at solar PV sites. Hence, solar PV sites may reduce bat activity over broad geographical scales.

The implications of these findings for bat conservation are considerable and understanding why solar PV sites are negatively affecting bat species is crucial, as has been done for other renewable energies (Frick et al., 2020). Bats are known to be affected by anthropogenic noise (Jones, 2008; Luo et al., 2014, 2015; Schaub et al., 2008), development associated with urbanised environments (Jung & Threlfall, 2016), the presence of smooth surfaces (Greif & Siemers, 2010; Greif et al., 2017; Ingeme et al., 2018) and habitat fragmentation (Meyer et al., 2016) all of which can be associated with ground-mounted solar PV sites.

There has been a "lack of consistency among evaluation or assessment methods" when assessing the ecological footprint of solar panels and other renewable energies (Burger & Gochfeld, 2012), as well as a disconnection between energy models and ecological assessment in policy which is well established in economic and emission modelling (Pang et al., 2014). In Europe, under legislation (The Conservation of Habitats and Species Regulations, 2017) it is an offence to deliberately disturb wild animals including bat species (Regulation 43, (1b)) and to affect significantly the local distribution or abundance of the species (Regulation 43, (2b)). The potential significant direct and indirect disturbance caused by solar PV on British bats foraging and commuting habitats, means that their impacts on bats should be assessed under legislation (The Town and County Planning (Environmental Impact Assessment) Regulations, 2017). This is in line with wind turbine developments and other energy generation projects.

Under this process, we suggest appropriate effort should be given to assess the presence of bats roosting, foraging and commuting within close proximity to the proposed development location due to the known risks of bats not tolerating anthropogenic disturbance, as detailed above. Where necessary, mitigation to support bats should be designed and activity should be monitored over extended periods. Mitigation may include, but is not limited to, reducing the density of panels within the site footprint, ensuring boundary habitat is maintained and improved in its area and diversity, and ensuring appropriate planting to improve foraging resources for those species identified as being at risk from the development (Boughey et al., 2011; Olimpi & Philpott, 2018). This should take place both within the solar PV sites and in the surrounding area. Where a solar PV site is proposed in proximity to a roost, or on a known important commuting route, of the species which have so far been identified as affected, then consideration should be given to whether alternate siting of the development, at a less sensitive location within the ecological landscape, would be more appropriate.

Further research is required to assess bat behaviour at and in proximity to solar PV sites to understand why some bats avoid solar PV sites, for example for example whether prey sources are negatively affected by solar PV developments or potentially panels are creating a collision risk with bats attempting to drink from them (Greif & Siemers, 2010; Greif et al., 2017; Horváth et al., 2010; Russo et al., 2012). Further work should be for the purposes of ensuring focused and effective mitigation that can be implemented and monitored through the EIA process.

Our study identifies some detrimental effects of solar PV sites for bat activity, and as such we conclude that assessing, mitigating and monitoring bat activity needs to be factored into solar PV development planning and operation. As highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and the Intergovernmental Panel on Climate Change biodiversity loss and climate change will continue to mutually reinforce each other unless tackled simultaneously (Pörtner et al., 2021). Successful mitigation measures at solar PV developments will be an opportunity to manage climate change while supporting biodiversity.

AUTHOR CONTRIBUTIONS

Elizabeth Tinsley, Gareth Jones and Jérémy S. P. Froidevaux conceived the ideas and designed methodology; and Elizabeth Tinsley collected the data; Elizabeth Tinsley and Jérémy S. P. Froidevaux analysed the data. Elizabeth Tinsley, Gareth Jones and Jérémy S. P. Froidevaux led the writing of the manuscript. All authors contributed critically to the drafts, including Sándor Zsebők and Kriszta Lilla Szabadi, and gave final approval for publication. *Statement of inclusion*: we include authors who contributed towards writing from a country outside of where the study was conducted.

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CONFLICT OF INTEREST STATEMENT

The authors do not have a conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available via the Dryad Digital Repository https://doi.org/10.5061/dryad.n2z34tn2p (Tinsley et al., 2023).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1. Table S1. Outputs of the full GLMMs relating the effects of the presence/absence of solar photovoltaic panels (treatment: solar vs. control site) in interaction with habitat type (boundary vs. open field) on species-specific bat activity and bat species richness. Marginal and conditional R^2 as well as delta *AICc* between the full and the null models are given. Delta *AICc* >2 indicates that the full model was more informative than the null one. Est., estimate; SE, standard error of the estimate.

Appendix S2. Table S2. The mean area (ha) of different landscape variables found around each of the recording sites/distance (km) to water to the control and solar study sites. Habitats were identified as per the UK Land Cover Map 2020. Pairwise comparisons were conducted using the Wilcoxon test for paired data. Significant differences are indicated in bold.

Appendix S3. Table S3. The approximate area (m^2) of the solar and control field at each site, with the corresponding open and boundary habitat where the bat detectors were placed. Open habitat management type: 1 grazed, 2 mown, 3 arable, Boundary habitat type: 4 hedgerow, 5 treeline, 6 woodland, 7 wet ditch.

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RESEARCH ARTICLE

Insectivorous bats alter their flight and feeding behaviour at ground-mounted solar farms

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Abstract

1. Efforts to mitigate the climate crisis result in a green-green dilemma: the development of renewable energy technology is required worldwide to reduce greenhouse gas emissions but can have negative impacts on biodiversity. Impacts are being documented for wind farms, but effects of solar farms (photovoltaic power stations) on habitat use of vertebrates remain extremely poorly known.
2. Using insectivorous bats as a biological model for high trophic levels, we tested whether the presence of ground-mounted solar farms affected flight and feeding behaviour. We assessed behaviour using three-dimensional flight path reconstruction systems from echolocation calls, via standardised paired sampling of 16 control and 16 solar farm (treatment) sites. We quantified bat flight and feeding behaviour as flight speed, sinuosity of flight trajectories, and the probability of emission of feeding buzzes (acoustic signatures of prey capture attempts), and demonstrated that feeding was characterised by slow, sinuous flight with feeding buzzes.
3. We recorded 15,273 three-dimensional bat positions, resulting in 1317 flight trajectories. We found strong behavioural responses to ground-mounted solar farms in two of three bat guilds and five of seven taxa. Specifically, bats shifted their flight towards faster (+10 to +44%) and straighter trajectories (+33%) with lower probability of prey capture attempts (−18 to −39%) at solar farms.
4. Since these changes in flight features are explicit indicators of a decrease in bat feeding behaviour, the implementation of ground-mounted solar farms is likely to result in reduced feeding habitat quality for bats.
5. *Synthesis and applications*: The negative effects of solar farms on bat flight and feeding behaviour should be considered when solar energy projects are planned. Research is needed to understand the mechanisms underlying the effects; for example, shading underneath solar panels may reduce plant biomass and therefore insect prey availability. Until exact mechanisms are identified, efforts should be made, first to avoid building solar farms on sites with great feeding potential

[redacted] share joint first authorship on this work.

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for bats, and second to offset residual effects by improving the surrounding land and/or solar farms to provide better foraging opportunities. In this way, populations of bats can be supported alongside the generation of renewable energy.

KEYWORDS
Chiroptera, feeding buzz, foraging behaviour, functionality loss, green-green dilemma, movement, renewable solar energy, three-dimensional (3D) acoustic tracking

1 | INTRODUCTION

The current climate crisis is driving the exponential development of renewable energy technologies worldwide, aimed at reducing our reliance on fossil energy and drastically reducing greenhouse gas emissions (IPCC, 2022). In the European Union, new policy initiatives have been implemented through the European Green Pact, with an ambitious aim of climate neutrality by 2050, which should result in a 40% increase in the share of renewable energy by 2030. In response to the current geopolitical context and the increasing need for energy independence, this pact has been further strengthened by the REPowerEU plan, which elevates the target to 45%. Although using renewable energy sources (i.e. solar, wind, geothermal, hydro, ocean and biomass) can contribute to the reduction in greenhouse gas emissions, the technology required is not exempt from negative impacts on biodiversity, thus generating a green-green dilemma (Gibson et al., 2017). This dilemma is particularly complex as the climate crisis is also accompanied by a biodiversity crisis; it is now recognised that these crises are interconnected and should be addressed together (Pörtner et al., 2021).

The impact of wind farms on biodiversity, and especially on flying fauna, is well-evidenced (Katzner et al., 2019; Voigt & Kingston, 2015), but responses of biodiversity to solar farms (photovoltaic power stations) remain poorly documented. There is an urgent need to understand how ground-mounted solar farms affect biodiversity, as the exponential growth of this renewable energy source is resulting in large-scale land-use conversion throughout Europe and elsewhere (IRENA, 2020). Ground-mounted solar farms could affect biodiversity in several ways, either directly due to the structures themselves or indirectly through changes induced by the structures. For instance, indirect effects could result from shade produced by solar panels inducing a shift in plant communities (Uldrijan et al., 2021) and a reduction in plant biomass and blooming (Armstrong et al., 2016; Graham et al., 2021). Solar panels can also attract diurnal aquatic insects through the polarised light they generate; thus, they represent an ecological trap (Horváth et al., 2010). Pollinator abundance, richness and diversity are strongly reduced underneath solar panel rows (i.e. in full shade conditions), and soil disturbance and vegetation removal during solar farm development displaces insect flower visitors (Graham et al., 2021; Grodsky et al., 2021). Finally, solar farms can create sensory traps for flying vertebrates (birds and bats) leading to attempts to drink from the smooth, horizontal panels or collisions with smooth, vertical panels (Greif et al., 2017), potentially generating additional energy costs. Collisions with panels also pose fatality risks (Smallwood, 2022).

Despite the important synthesis and review work of Smallwood (2022), effects of the installation of solar farms on habitat use by vertebrates remain poorly documented. There have been only three studies: one shows that solar farms lead to reduced bird species richness and density (Visser et al., 2019), and two show that they lead to reduced activity of several insectivorous bat species (Szabadi et al., 2023; Tinsley et al., 2023). Perturbations of insectivorous bats, which occupy high trophic levels, are likely to be linked to reductions in the abundance of their insect prey, which could be generated by reduced plant biomass in the shady conditions under solar panels (Armstrong et al., 2016; Graham et al., 2021). Bats represent a biological model that is very sensitive to local changes in prey distribution and have the ability to select suitable patches for foraging at a fine scale (Barré et al., 2017). Following this hypothesis, insectivorous bats at solar farms should exhibit less foraging behaviour than those in the surrounding semi-natural habitats without solar panels. An explicit way to study bat foraging behaviour is to quantify the acoustic signatures of bats' prey capture attempts (hereafter referred to as 'feeding buzzes') in recordings of their echolocation calls. Tools have recently been developed to detect feeding buzzes automatically from the characteristics of the calls (Roemer et al., 2021), but feeding buzzes can be rare (they usually make up <2% of acoustic recordings; Barré et al., 2020). Other behavioural metrics increasingly used in bat research, such as flight speed and sinuosity (Barré et al., 2020; Gilmour et al., 2021; Grodzinski et al., 2009; Polak et al., 2011), may be effective proxies of feeding flight, as has been demonstrated for *Pipistrellus kuhlii* and *Myotis daubentonii* (Grodzinski et al., 2009; Jones & Rayner, 1988). More specifically, feeding flight is expected to be associated with lower flight speed and higher flight sinuosity than commuting flight. Since such changes in flight behaviour could also mirror obstacle avoidance (Falk et al., 2014), flight speed and sinuosity in bats can be considered as complementary metrics to feeding buzzes in the detection and quantification of feeding behaviour.

We aimed to assess the effects of ground-mounted utility-scale solar farms on bat feeding behaviour by using three-dimensional flight path reconstruction systems from echolocation calls, through a paired sampling design. We quantified bat feeding behaviour by using the probability of feeding buzz emission, flight speed and sinuosity of flight trajectories. To check the validity of these three metrics as indicators of feeding behaviour in our data, we first assessed the extent

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to which flight speed and sinuosity were related to the probability of feeding buzz emission. We hypothesised that decreasing flight speed and increasing flight sinuosity would be associated with an increasing probability of detecting feeding buzzes. Then, we predicted that feeding buzz emission and flight trajectory sinuosity would be lower, and flight speed would be higher, at solar farms than at control sites, as the insect prey resource was expected to be less abundant at sites in which less light reached the ground due to shading by solar panels.

2 | MATERIALS AND METHODS

2.1 | Study area

With permission from the Compagnie Nationale du Rhône (CNR, a solar farm management company), the study was carried out at nine ground-mounted utility-scale solar farms in the Rhône Valley in France (Figure 1a,b), a region supporting high activity of several bat species, including *P. kuhlii*, *Pipistrellus nathusii* and *Pipistrellus pygmaeus* (Bas et al., 2022). We selected solar farms for which treatment and control sites could be standardised regarding landscape composition and distance to foraging habitats (e.g. water bodies and woodland edges) so that similar sites could be found to form each pair (see Section 2.2 for more details). We have ensured that there are no obstacles to bat flight other than the solar panels in control and treatment sites. The surface areas of the solar farms varied between 2.5 and 25 ha (median = 7.4 ha); their capacities varied between 2.5 MW and 14 MW (median = 4.2 MW). Seven of the nine solar farms had fixed-angle panels (roughly 25°), the other two had mobile-angle (mono-axial) panels on the east–west axis (placed horizontally during surveys). The surface of the panels was rough, with fine crenelations. Solar panels were on average 2.4 ± 0.4 m high (mean ± standard deviation) and 3.4 ± 1.1 m wide; the distance between the solar panel rows was 4.9 ± 1.3 m. Solar panels were installed on grazed or mown grasslands sown with native plant species which were 0.2 to 1.1 m in height and covered 20 to 90% of the ground surface (Table S1). The sites used for solar farms were either old industrial sites or embankments resulting from the canalisation of the River Rhône and were located 233 ± 192 m from the river bank. At the landscape scale (500 m around the study sites), the land use was dominated by agricultural land (44%), woodland (34%) and impervious surfaces (16%).

2.2 | Sampling design and three-dimensional acoustic tracking

To assess the effects of ground-mounted solar farms on bat feeding behaviour, we implemented a paired sampling design, each pair consisting of one site within a solar farm (treatment) and one matched control site located outside the farm (control; Figure 1c). Solar and control sites within a pair were separated by at least 100 m (to avoid simultaneous double counting of bats) and by no more than 500 m and were sampled simultaneously on the same night, in order to avoid differences in weather conditions and landscape context between solar and control sites. For each pair, we standardised the vegetation height and cover at the sampling location using visual estimations made by two observers (Alice Baudouin and Kévin Barré), the distance to the nearest woodland edge and water body and the proportion of woodland (both coniferous and deciduous) within a 1000 m radius. These parameters were statistically similar in the two sites of each pair (Table S1). Each night, we sampled one or two pairs simultaneously, at one solar farm, during the first 3 h after sunset. In total, 16 pairs (16 control and 16 solar sites) were sampled on nine nights from September 21st to 30th, 2022, during suitable weather conditions for insects and bats (mean temperature at night: 11.4–20°C; wind speed: 0–5.5 m/s; no rain; Table S1).

We acoustically monitored bat flight trajectories by recording three-dimensional positions of bats using the Trajecto V1 system (hereafter called 'the microphone array') from Suva-tech (Phnom-Penh, Cambodia; https://www.suva-tech.com/). This built-in system contains four microphones (FG 23329, Knowles Acoustics, Itasca, IL USA), which record bat echolocation calls from 1 to 250 kHz. The microphones in the array were arranged in a horizontal triangle shape, with one microphone in each corner and one in the middle (Figure 1d). At solar sites, the microphone array was always placed in the middle of a gap between two rows of solar panels, at more than 25 m from the edge of the solar farm, with the *x* axis (Figure 1d) oriented parallel to the rows of panels. We used the same placement pattern in term of microphone arrangement and *x* axis azimuth at control sites. Within the detection range (roughly 30 m radius), bat positions were continuously assessed by the system using the time difference of arrival of bat echolocation calls between microphones (Ing et al., 2016; Koblitz, 2018). From three-dimensional positions, we reconstructed complete bat flight trajectories following the approach described by Barré et al. (2020, 2021). In total during the study, flight trajectories were 3.2 ± 2.9 s in duration and contained 11.6 ± 8.3 positions (i.e. echolocation calls). Solar panels can prevent sound propagation, creating 'acoustic blind spots' in which echolocation calls cannot be detected if a panel is present between the bat and the microphone. Hence, on solar sites, the sphere of acoustic detection was truncated by acoustic blind spots. In order to avoid differences in detection volumes between control and solar sites, we filtered out the three-dimensional positions at each control site where bats could not be detected at its paired solar site because of the acoustic blind spots. Specifically, locations of bats at a control site that corresponded to a location behind a panel at the paired solar site were eliminated.

FIGURE 1 Map of the study area (a) and the 16 pairs of solar farms sampled for bats by using the microphone arrays (b), an example of two pairs sampled the same night (c), a schematic overview of the set-up used to reconstruct bat trajectories and compute behavioural metrics from echolocation calls (d), and a spectrogram showing the expected change in flight behaviour within a trajectory from prey search phase echolocation calls to the feeding buzz emission phase for prey capture: as flight speed decreases during the search and approach phase before a feeding buzz, sinuosity increases (e).

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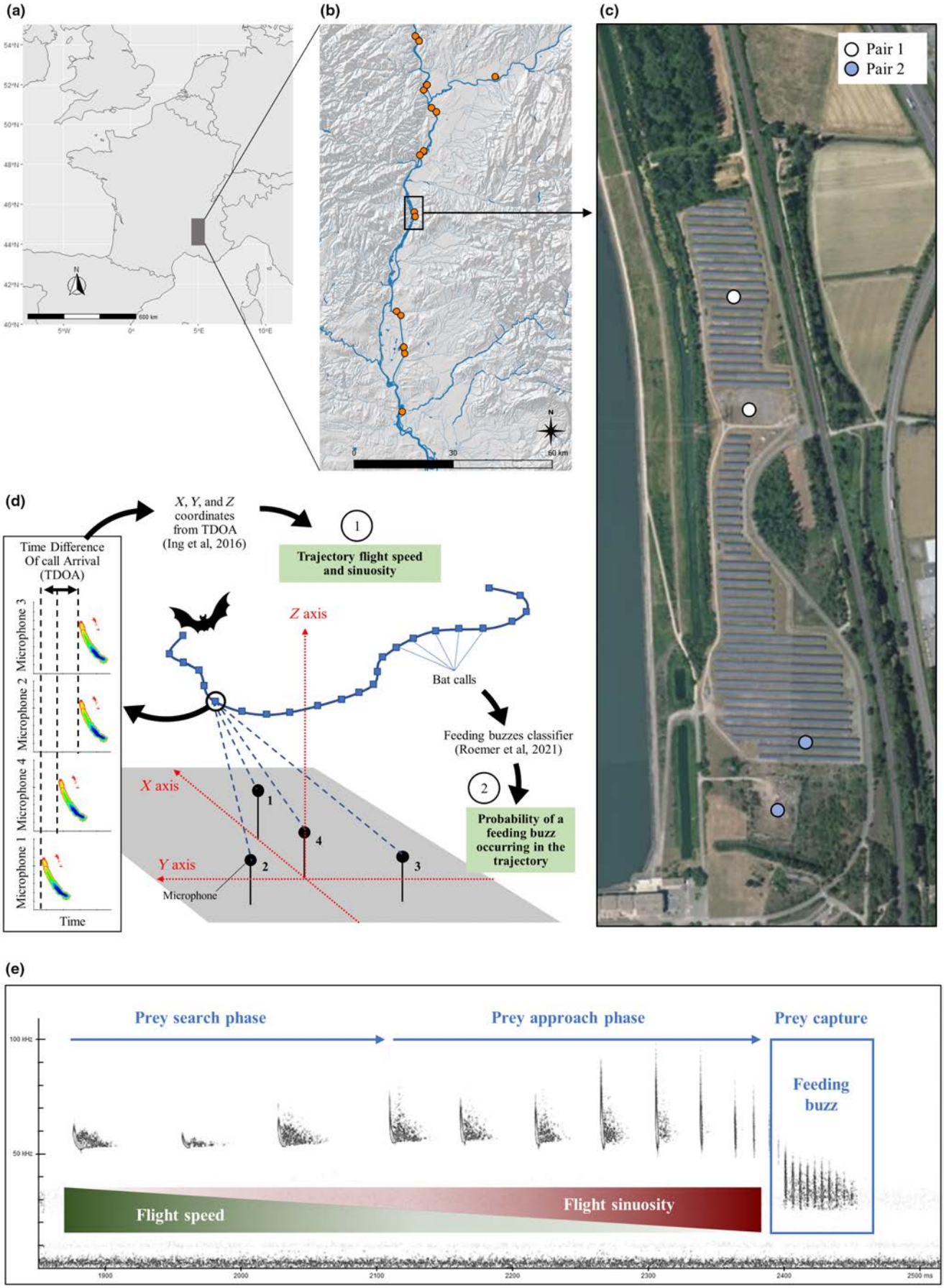

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2.3 | Assigning species and feeding buzz probability to trajectories

Each bat recording made via the microphone array, in the form of a half-second sound file, was classified to the closest taxonomic level using the Tadarida software (Bas et al., 2017), and assigned a feeding buzz probability using a sonotype classifier (Roemer et al., 2021). The probability of feeding buzz emission was calculated by the classifier based on the prey capture phase (i.e. the feeding buzz itself) following the prey approach phase, which is characterised by deceleration (Figure 1e; Jones & Rayner, 1988). Then, we linked each identification and buzz probability to a trajectory based on the same sound file. When several bat identifications were proposed for a single trajectory, we associated each trajectory with the single species that was most represented and had the highest automated identification confidence score.

Identification of bats to the species level from echolocation calls is problematic for some species, so we limited the identification level of species belonging to the *Myotis* genus to *Myotis* spp. To increase the generality of the results and the value of the data, we also pooled species into three functional guilds based on their echolocation call structure and foraging strategies: long-range echolocators (LRE, including open-space species from *Eptesicus* and *Nyctalus* genus), mid-range echolocators (MRE, including edge-space species from the *Pipistrellus* genus, *Hypsugo savii* and *Miniopterus schreibersii*), and short-range echolocators (SRE, including narrow-space species from *Myotis* and *Plecotus* genus and *Barbastellus barbastella*). We restricted the analyses to six species (*Pipistrellus pipistrellus*, *Pipistrellus kuhlii*, *Pipistrellus nathusii*, *Pipistrellus pygmaeus*, *Nyctalus leisleri* and *Plecotus austriacus*), one species group (*Myotis* spp.) and three guilds (LRE, MRE and SRE), for which the number of trajectories recorded was higher than the number of sites (Table S2).

2.4 | Computing flight behaviour metrics

Based on the three-dimensional positions of bats in reconstructed trajectories, we computed (i) mean trajectory flight speed, (ii) minimum trajectory flight speed and (iii) trajectory sinuosity. Flight speed (V) between two positions was computed as follows (Equation 1):

$$Vi = \frac{\sqrt{(xi - xj)^2 + (yi - yj)^2 + (zi - zj)^2}}{ti - tj} \quad (1)$$

where x, y and z represent distances to microphone 1 (Figure 1d) for each of the three-dimensional axes, and t is the time of call arrival to the microphone array of a given position i and its previous position j.

The sinuosity of the trajectory (S) was computed as follows (Equation 2):

$$St = \frac{\sum_{i=2}^{N} \sqrt{(xi - xi-1)^2 + (yi - yi-1)^2 + (zi - zi-1)^2}}{\sqrt{(xN - x1)^2 + (yN - y1)^2 + (zN - z1)^2}} \quad (2)$$

where x, y and z represent distances to microphone 1 for each of the three-dimensional axes, N is the last position of the trajectory t, while 1 is the first position and i is the number of each individual position starting from the second position.

When computing average flight speed of the bat in each trajectory, we filtered out positions with flight speed >20 m/s, as higher values are unlikely to be accurate (O'Mara et al., 2021); this resulted in us removing 25.5% of positions and 2% of trajectories. Similarly, we filtered out trajectories with sinuosity values higher than the 95% quantile of this metric (i.e. values of >70), to eliminate outliers.

Finally, based on automated classification of feeding buzz probability, we computed the (iv) mean feeding buzz probability and (v) maximum feeding buzz probability for each trajectory.

2.5 | Statistical analysis

To test for effects of the presence of photovoltaic panels on bat feeding behaviour, we conducted statistical analysis following three steps. First, we assessed the robustness of the feeding buzz probability produced by the automated classifier as an indicator of the real feeding behaviour. Second, we assessed the extent to which the other flight behaviour metrics (flight speed and trajectory sinuosity) were effective proxies of feeding behaviour. Finally, we tested whether the feeding buzz probability and flight behaviour metrics differed between solar and control sites. The following sections present these three analysis steps.

2.5.1 | Robustness of the feeding buzz probability estimation

We first assessed the extent to which feeding buzz probability produced by the classifier built by Roemer et al. (2021) was a good indicator of feeding behaviour. To do this, we modelled the relationship between 141 stratified manual checks of buzz presence/absence made by the authors and the buzz probability provided by the classifier, using generalised linear models associated with a binomial distribution (R package lme4).

2.5.2 | Relationships between feeding buzz probability and flight behaviour metrics

Since flight behaviour metrics (i.e. trajectory flight speed and sinuosity) have seldom been tested as proxies of feeding behaviour, we first modelled the relationships between the mean and maximum feeding buzz probability as response variables, and (i) mean trajectory flight speed, (ii) minimum trajectory flight speed and (iii) trajectory sinuosity as explanatory variables, using Generalised Linear Mixed Models (GLMM; R package glmmTMB) associated with Gaussian distributions. We included the pair identifier as a random effect to account for the

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paired sampling design, and the quadratic terms of each explanatory variable, as we expected nonlinear relationships.

2.5.3 | Effects of solar farms on bat flight and feeding behaviour

We assessed whether bat feeding behaviour differed between solar and control sites. To do this, we built GLMMs using either mean or minimum trajectory flight speed, trajectory sinuosity, or mean or maximum feeding buzz probability as response variables, and the type of site (i.e. solar or control) as the explanatory variable. We used Gaussian distributions for mean and minimum flight speed and sinuosity, and beta distributions for mean and maximum feeding buzz probability. We included the pair identifier as a random effect, and, when required, we adapted the weight of response variables to the associated precision of positions (i.e. with the inverse of the imprecision squared, to give more weight to the most precise positions; Barré et al., 2020, 2021) by adding a precision weight term in GLMMs (see Supporting Information S1 for more details). For Gaussian models, we normalised response variables using the best transformation method, assessed using the R package bestNormalize. Finally, we checked that residuals of models did not exhibit issues using the R package DHARMa. All analyses were performed with R v.4.2.0 (R Core Team, 2020).

3 | RESULTS

3.1 | Three-dimensional acoustic tracking

We recorded a total of 15,273 bat positions. Of these, 87% were produced by mid-range echolocators (MRE): *P. nathusii* (38%) and *P. pygmaeus* (37%) were the most represented, followed by *P. kuhlii* (14%) and *P. pipistrellus* (11%). Short-range echolocators (SRE) produced 7% of positions, which were shared between *Myotis* spp. (57%) and *P. austriacus* (35%). Long-range echolocators (LRE) produced 5% of positions: *N. leisleri* was dominant (79%), followed by *N. noctula* (11%). From the three-dimensional positions we reconstructed a total of 1317 trajectories, mainly of MRE (82%), followed by SRE (9%) and LRE (9%) (Table S2). On average, trajectories contained 12.5 positions for MRE, nine positions for SRE, and six positions for LRE.

3.2 | Robustness of feeding buzz probability estimations and correlations with flight behaviour metrics

We found that the feeding buzz probability from the automated classifier reliably estimated the probability of feeding buzz presence as assessed by manual checks, with a strong positive relationship (classifier probabilities of 0 and 1 corresponded to buzz detection success probabilities of 0.08 and 0.99, respectively; $p = 2.04^{e\text{-}08}$, estimate ± SE = 3.96 ± 0.71; Figure 2a). Further analyses confirmed that the flight behaviour metrics flight speed and trajectory sinuosity were relevant predictors of feeding behaviour. Specifically, we found that increasing mean or maximum feeding buzz probability in the trajectory was correlated with decreasing trajectory flight speed (Figure 2b,c,e,f; Table S3) and increasing trajectory sinuosity (Figure 2d,g; Table S3). Therefore, feeding was characterised by slow, sinuous flight with feeding buzzes.

3.3 | Effect of solar farms on bat flight and feeding behaviour

For five bat taxa (*P. kuhlii*, *P. pygmaeus*, *P. austriacus*, and the guilds MRE and SRE), we found that mean flight speed was significantly higher at solar sites than at control sites. Mean flight speed was significantly lower at solar sites than at control sites for *P. nathusii* (Figure 3a; Table 1 and Table S4). Minimum flight speed was significantly higher at solar sites than at control sites for the SRE guild, *P. kuhlii*, *P. pygmaeus* and *P. austriacus* (Figure 3b; Table 1 and Table S4).

We also found that mean feeding buzz probability of the trajectory was significantly lower at solar sites than at control sites for the MRE guild, *P. nathusii* and *P. pipistrellus*, and the same pattern was found for the maximum feeding buzz probability of the trajectory for *P. pipistrellus* (Figure 3c,d; Table 1 and Table S4). Furthermore, the trajectory sinuosity was significantly lower at solar sites than at control sites for the SRE guild only (Figure 3e; Table 1 and Table S4).

4 | DISCUSSION

In line with our hypothesis, insectivorous bats of several species in two functional guilds showed strong behavioural responses to ground-mounted utility-scale solar farms, by shifting their flight towards faster and straighter trajectories with lower probability of feeding buzz emission. Since these changes in flight features are explicit indicators of a decrease in bat feeding behaviour, it is clear that the implementation of solar farms results in a reduction of habitat quality for bats.

A mechanism to explain the reduced feeding flight behaviour at solar farms could be the reduction of prey biomass by trophic cascade. This mechanism is consistent with studies showing a reduction of global biomass, floral abundance and blooms in plant communities underneath solar panels (Armstrong et al., 2016; Graham et al., 2021), which could, in turn, reduce insect prey availability (Graham et al., 2021). However, this mechanism must be interpreted with caution, as Graham et al. (2021) only studied diurnal pollinators, and no researchers, to our knowledge, have

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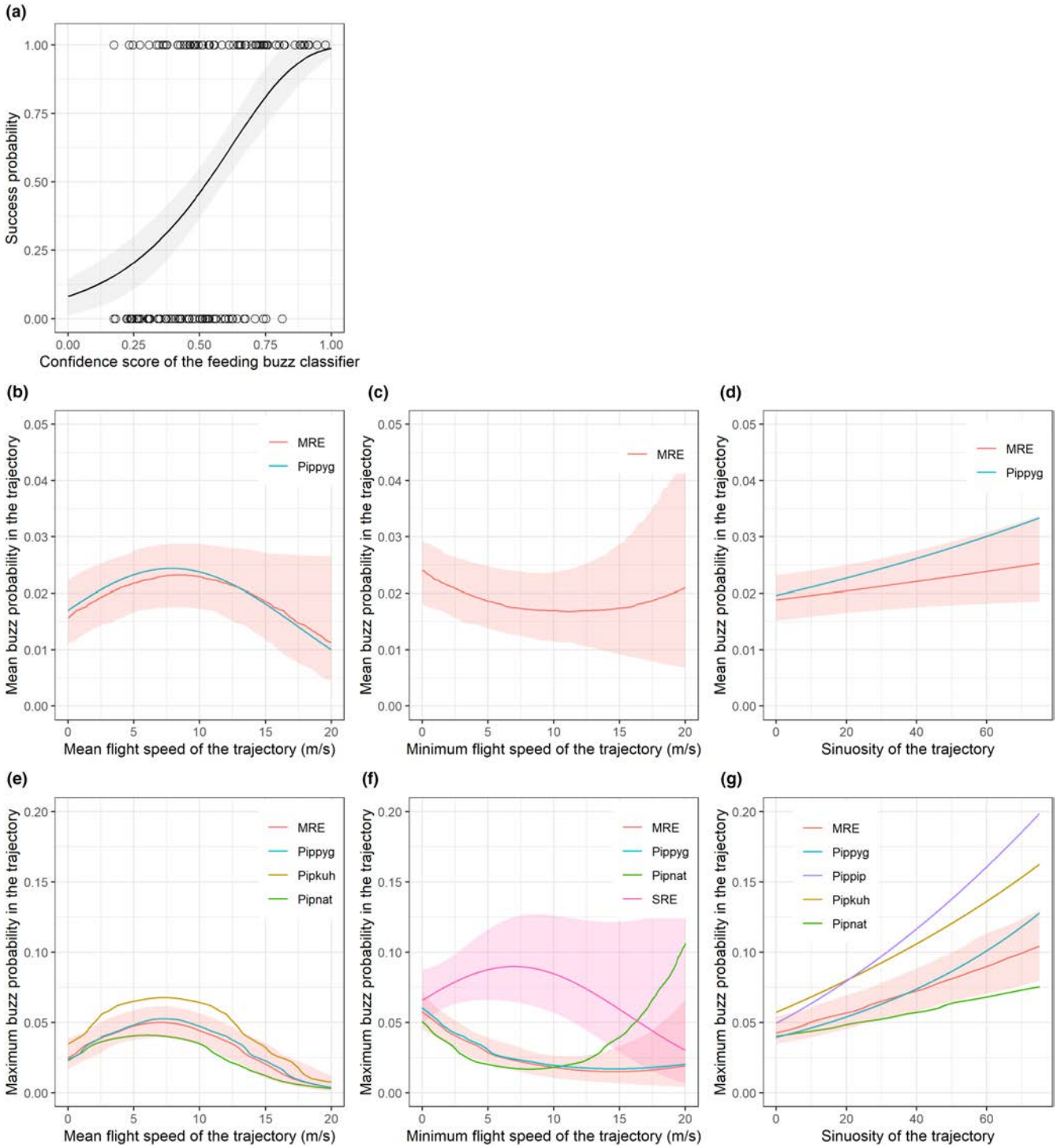

FIGURE 2 Feeding by bats is characterised by slow, sinuous flight with feeding buzzes. Test of the robustness of bat feeding buzz probability estimation, using logistic regression to compare success probability from manual checks with the confidence score of the feeding buzz classifier from automated identification (Roemer et al., 2021; a). Relationships between the mean (b–d) and maximum (e–g) feeding buzz probability of the trajectory, and the mean flight speed (b, e), the minimum flight speed (c, f), and the sinuosity of the trajectory (d, g), from generalised linear mixed models for bat guilds and species (MRE: mid-range echolocators; Pippyg: *P. pygmaeus*; Pippip: *P. pipistrellus*; Pipkuh: *P. kuhlii*; Pipnat: *P. nathusii*; SRE: short-range echolocators). Only significant effects ($p < 0.05$) are represented, and 95% confidence intervals are shown as shaded areas for guilds.

assessed variation in the abundance of the nocturnal insects that are potential prey for bats in response to solar farms. An alternative hypothesis is that insects are attracted by the polarised light produced by the smooth surface of solar panels (Horváth et al., 2010). Such an attraction could reduce the amount of insects available in the aerial volume at solar farms by concentrating

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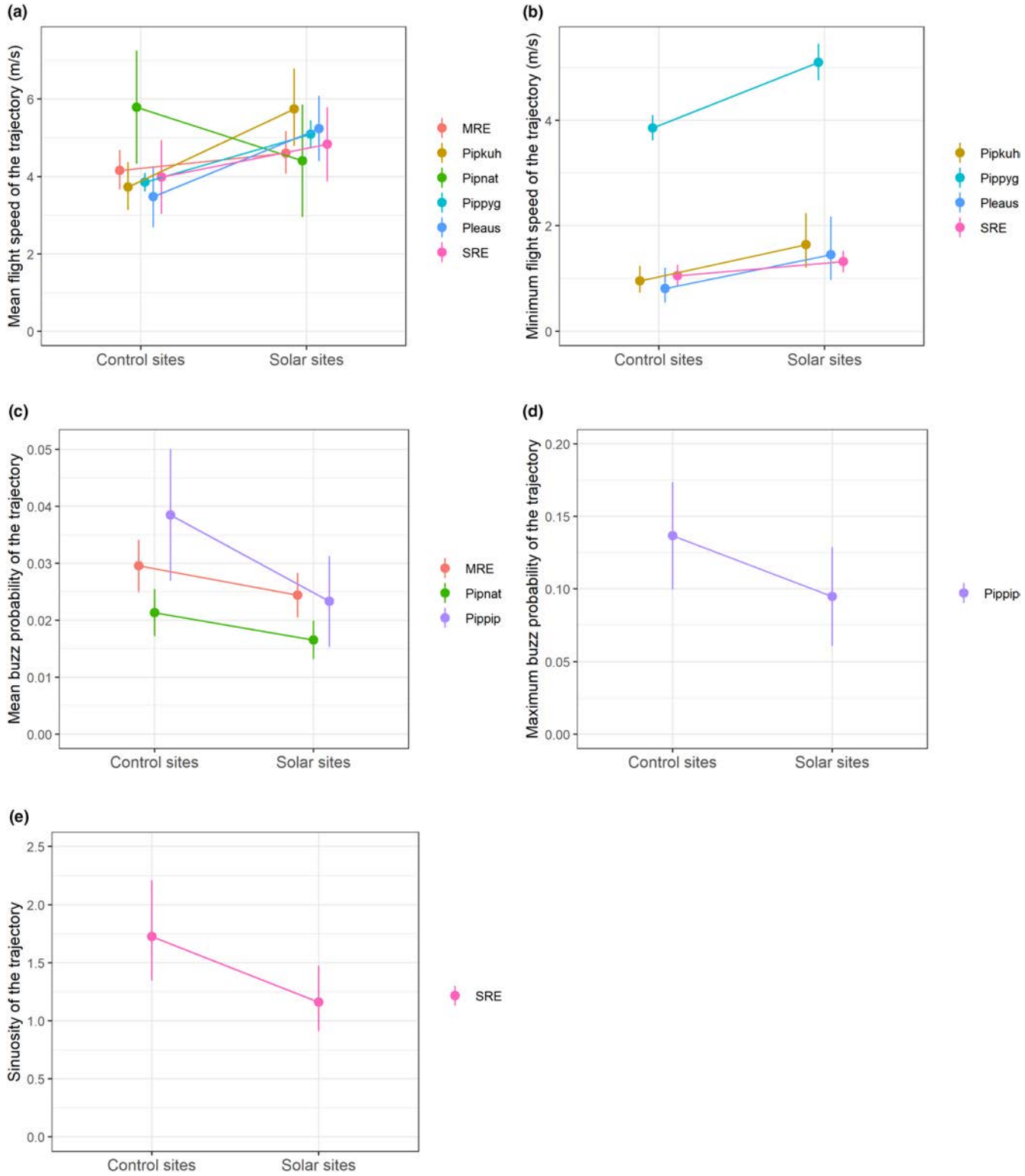

FIGURE 3 Effects of solar farms on the flight and feeding behaviour of bats: predicted mean (a) and minimum (b) flight speed, mean (c) and maximum (d) feeding buzz probability, and sinuosity (e) of trajectories at paired control and solar sites, from generalised linear mixed models, for bat guilds and species (MRE: mid-range echolocators; Pippyg: *P. pygmaeus*; Pippip: *P. pipistrellus*; Pipkuh: *P. kuhlii*; Pipnat: *P.nathusii*; Pleaus: *P. austriacus*; SRE: short-range echolocators). Only significant effects ($p < 0.05$) are represented, and vertical bars represent 95% confidence intervals.

them on the surface of the solar panels where aerial hawking bats (i.e. non-gleaning bats) are less able to capture them (Schnitzler & Kalko, 2001). Further studies could disentangle the effects of changes in plant community traits and polarised light induced by solar panels on the availability and spatial distribution of nocturnal insect prey consumed by bats. Finally, as a last potential

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TABLE 1 Effects of solar farms on the flight and feeding behaviour of bats: predicted values and associated 95% confidence intervals (in square brackets) of each feeding behaviour metric at solar and control sites, for each bat guild and species from generalised linear mixed models, and associated changes in these values at solar sites compared to control sites (MRE: mid-range echolocators; Pippyg: *Pipistrellus pygmaeus*; Pippip: *Pipistrellus pipistrellus*; Pipkuh: *Pipistrellus kuhlii*; Pipnat: *Pipistrellus nathusii*; Pleaus: *Plecotus austriacus*; SRE: short-range echolocators). Only significant effects ($p < 0.05$) are represented.

		Predicted values [95% CI]		
Response variable	**Taxa**	**Solar sites**	**Control sites**	**% of change at solar versus control sites**
Mean flight speed (m/s)	Mid-range echolocators	4.61 [4.08, 5.17]	4.16 [3.67, 4.68]	9.7
	P. pygmaeus	5.10 [4.75, 5.45]	3.85 [3.62, 4.09]	24.4
	P. kuhlii	5.75 [4.79, 6.79]	3.73 [3.13, 4.37]	35.1
	P.nathusii	4.41 [2.96, 5.86]	5.79 [4.33, 7.25]	−31.4
	Short-range echolocators	4.83 [3.87, 5.79]	3.98 [3.03, 4.94]	17.5
	P. austriacus	5.24 [4.40, 6.08]	3.48 [2.69, 4.27]	33.7
Minimum flight speed (m/s)	*P. kuhlii*	1.64 [1.20, 2.24]	0.95 [0.73, 1.25]	41.9
	P. pygmaeus	5.10 [4.75, 5.45]	3.85 [3.62, 4.09]	24.4
	Short-range echolocators	1.32 [1.12, 1.52]	1.06 [0.85, 1.26]	20.1
	P. austriacus	1.45 [0.97, 2.17]	0.81 [0.55, 1.21]	44.1
Mean buzz probability	Mid-range echolocators	0.024 [0.020, 0.028]	0.030 [0.025, 0.034]	−17.5
	P. pipistrellus	0.023 [0.015, 0.031]	0.038 [0.027, 0.050]	−39.4
	P.nathusii	0.017 [0.013, 0.020]	0.021 [0.017, 0.025]	−22.5
Maximum buzz probability	*P. pipistrellus*	0.095 [0.061, 0.129]	0.137 [0.010, 0.174]	−30.7
Sinuosity	Short-range echolocators	1.16 [0.91, 1.45]	1.72 [1.35, 2.21]	−32.7

mechanism, solar panels could add clutter to the foraging environment, which could impose structural (more objects) as well as acoustic (more echoes to interpret and reflections of echolocation calls) challenges to bats (Greif et al., 2017). However, future studies on this type of panel could combine three-dimensional acoustic tracking with high-resolution imagery methods to assess the effects of such potential sensory traps and their impact on prey capture success, and on the risk of collision and confusion with water surfaces for drinking.

The lower mean flight speed of *P. nathusii* at solar sites than at paired control sites is the only result that does not support our original hypothesis. Although we have no clear explanation for this result, the lower average buzz probability we found at solar sites does support the hypothesis and confirms that feeding habitat quality was reduced at solar sites for *P. nathusii*. In addition, the fact we did not detect differences in buzz probability between solar and control sites for taxa other than MRE and *Pipistrellus* spp. is not surprising, as these less common taxa had very low buzz rates, which decreases statistical power and prevents any effects from being detected (Schnitzler & Kalko, 2001).

The magnitude of behavioural change due to solar farms that we report is strong, which suggests a major loss of habitat feeding functionality for bats. We believe that this loss of functionality could contribute to a decrease in the quality of the landscape as perceived by bats and force them to travel greater distances to feed (Laforge et al., 2021). However, these results do not inform us about the net consequences that this decreasing habitat quality may have on population dynamics. Indeed, it is difficult to quantify feeding loss accurately, since bats, especially gleaning species, do not always emit a feeding buzz when capturing an insect, and a feeding buzz does not always indicate a successful capture (Britton & Jones, 1999; Stidsholt et al., 2023; Surlykke et al., 2003). We were not able to carry out aerodynamic modelling, as we did not have morphological data for bat populations at the time and sites we sampled, so we were unable to assess whether the flight speeds we recorded at control sites were energetically optimal speeds. Consequently, we could not determine whether the increase in flight speed at photovoltaic sites represented a shift from optimal foraging to commuting flight (i.e. minimising energy expenditure per time for a given minimal power speed, or minimising it per distance for a given maximal range speed), or an intermediate suboptimal shift. In both cases, given the extent of the increase in flight speeds leading to a greater probability of commuting, it is very likely that the presence of solar panels resulted in additional energy costs for the individuals (Grodzinski et al., 2009; Norberg & Rayner, 1987). Finally, although the sites studied covered a large geographical area, sampling only spanned 9 days in September, so future studies should confirm these patterns in other seasons and bioclimatic areas.

Our results show that even development projects that do not require total sealing of the soil for building or paving can lead to reduced

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habitat quality. The resulting functionality loss is a form of habitat loss for bats, which should be addressed in the context of the mitigation hierarchy, a well-established legal framework to counteract impacts of development projects on biodiversity, by (i) avoiding impacts (e.g. avoiding spatial locations where high impact is expected due to the abundance of food resources, such as wetlands), (ii) reducing impacts (e.g. limiting the land area used for solar farms) and, as a last resort, (iii) offsetting residual impacts on biodiversity (e.g. creating new habitats; Business and Biodiversity Offsets Programme (BBOP), 2012; Gardner et al., 2013). As the exact mechanisms triggering the effects we documented remain unknown, reduction levers seem to be limited, and efforts should thus be made firstly, to avoid using sites with the greatest feeding potential for bats as solar farms, and secondly, to offset the residual effects by improving the carrying capacity of the food web within and around solar farms development projects (Tölgyesi et al., 2023). For example, the composition of plant communities at solar farms could be improved by sowing native flowering plant species (Peter et al., 2021) by creating agroecological infrastructures, such as hedgerows and flower fields supporting insects (Froidevaux et al., 2019; Krings et al., 2022), or by livestock grazing providing dung-feeding insects and avoiding the need to cut and remove the vegetation (Zaplata, 2023), that are widely known to benefit feeding bats. In this way, the transition to renewable energy can continue while negative effects on bats are minimised.

AUTHOR CONTRIBUTIONS

Kévin Barré and Alice Baudouin designed the study and collected the data. Kévin Barré created the workflow for data preparation and processing. Kévin Barré conducted the analyses with the support of Christian Kerbiriou and Alice Baudouin. Kévin Barré led the writing of the manuscript with the input of Christian Kerbiriou, Jérémy S. P. Froidevaux, Alice Baudouin and Vivien Chartendrault.

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CONFLICT OF INTEREST STATEMENT

CNR is a developer of photovoltaic projects which partially funded the study, and did not influence the analyses, interpretations, discussions and conclusions of the study. None of the authors was employed by any of the funders prior to, or at the time of the submission of the article. Authors declare having no other competing interest.

DATA AVAILABILITY STATEMENT

Data available via the Zenodo platform https://doi.org/10.5281/zenodo.10149959 (Barré et al., 2023).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Solar farms where acoustic sampling for bats was carried out: summary of sampling dates. weather during field sessions. type of solar panel. and information about herbaceous vegetation. and landscape features for each pair sampled. Values are shown separately for control (C) and solar (S) sites of each pair. Wilcoxon signed rank tests show that the landscape composition did not significantly differ between control and treatment sites.

Table S2. Summary of the number of three-dimensional positions and trajectories recorded for each bat guild and species.

Table S3. Summary of the relationships (estimates. standard errors and *p*-values) between trajectory feeding buzz probability variables and flight behaviour metrics (mean and minimum flight speed and sinuosity) for each bat guild and species from generalised linear mixed models (***$p<0.001$; **$p<0.01$; *$p<0.05$). N = the number of bat trajectories included in models.

Table S4. Estimates. standard errors and *p*-values of the effect of the presence of solar panels on feeding behaviour metrics for each bat guild and species from generalised linear mixed models (***$p<0.001$; **$p<0.01$; *$p<0.05$).

Supporting Information S1. Computing imprecision of 3D positions and accounting for it in the modelling.

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Plant and soil responses to ground-mounted solar panels in temperate agricultural systems

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LETTER

Plant and soil responses to ground-mounted solar panels in temperate agricultural systems

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Abstract

In the move to decarbonise energy supplies to meet Net Zero targets, ground-mounted solar farms have proliferated around the world, with uncertain implications for hosting ecosystems. We provide some of the first evidence on the effects of ground-mounted solar panels on plant and soil properties in temperate agricultural systems. We sampled 32 solar farms in England and Wales in summer 2021. Plant cover and aboveground biomass, as well as soil nutrients and physiochemical properties, were quantified on land underneath solar panels, in the gaps between rows of solar arrays, and in control land (pasture) adjacent to three solar farms. Plant cover and aboveground biomass were significantly lower under solar panels than in the gaps between solar arrays and in pastures. Soil compaction was 14.4% and 15.5% higher underneath solar panels than in gaps and pastures, respectively. Soil organic carbon was 9% lower under solar panels than in gaps, while particulate organic matter was 29.1% and 23.6% lower under solar panels than in gaps and pastures, respectively. Soil mineral nitrogen was 30.5% higher under solar panels than in gaps, while soil (plant-available) phosphorus was approximately 60% higher in solar farm soils than in pasture soils. Reductions in solar radiation and changes to microclimate caused by solar panels may be driving lower plant productivity and growth, with consequences for nutrient cycling and soil properties. However, impacts must be considered in light of the previous land use and the total land area under solar panels, in the gaps between solar arrays, and around the margins of the solar farm. Our findings can inform solar farm design and management options (e.g. increase the proportion of land unaffected by solar panels, enhance plant cover under solar panels) to ensure the long-term provision of ecosystem services (e.g. soil carbon storage) within this fast-growing land use.

1. Introduction

The global deployment of renewable energy technologies has accelerated in the last decade in response to expanding policy support, growing energy security concerns, and the need to meet Net Zero targets to mitigate climate change (IEA 2024). Solar photovoltaic (PV) technologies are currently leading this growth in renewable energy (Ember 2024), mostly in the form of ground-mounted solar farms due to policy incentives for large-scale developments and declining module prices (IEA 2023). The increase in

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solar farm development is expected to continue in the coming decades (Nijsse *et al* 2023) and is likely to intensify competition for land to produce food, generate energy, and conserve nature (Capellán-Pérez *et al* 2017). It is thus becoming increasingly important to quantify and understand solar farm impact on ecosystems, especially considering the potential to manage solar farms for positive environmental outcomes (Randle-Boggis *et al* 2020).

Solar farms are commonly built on agricultural land (Tinsley *et al* 2024) and managed as grasslands in temperate regions (Carvalho *et al* 2023, 2024a), offering both risks and opportunities for ecosystem health (Randle-Boggis *et al* 2020). Existing data indicate effects on microclimate and ecosystem processes (Armstrong *et al* 2016) and on plant and soil properties (Lambert *et al* 2021). For instance, the installation of PV arrays may have negative environmental impacts by disrupting soil aggregate stability and the native vegetation, resulting in topsoil erosion (Hernandez *et al* 2014). The removal of topsoil during construction can also reduce soil carbon (Choi *et al* 2020), nitrogen, and phosphorus (Geissen *et al* 2013), as well as increase soil bulk density and affect the soil's structural and hydraulic properties (Geissen *et al* 2013, Udom *et al* 2018). However, solar farms can also have positive environmental impacts, and have the potential to deliver several co-benefits beyond low-carbon electricity when compared to conventional fossil fuel sources (Turney and Fthenakis 2011). For instance, construction and land management techniques conducive to providing local biodiversity benefits (e.g. allocating space for semi-natural habitats) can help restore degraded habitats (Gazdag and Parker 2019, Semeraro *et al* 2020) and result in enhanced ecosystem services (Randle-Boggis *et al* 2020). Despite this recent evidence, relatively little is known of the effects of solar farms on plant and soil properties in temperate agricultural systems. This is an important knowledge gap since solar farms are expected to become increasingly common features of agricultural landscapes in coming decades as part of the low-carbon energy transition (IEA 2023).

The aim of this study was to investigate the effects of ground-mounted solar panels on plant and soil properties across solar farms in England and Wales. We compared plant (cover and aboveground biomass) and soil (organic carbon, mineral-associated organic matter (MAOM), particulate organic matter (POM), total nitrogen, C/N ratio, mineral nitrogen, nitrate, plant-available phosphorus, bulk density, and pH) properties from areas underneath solar panels to areas between rows of solar arrays and to control land adjacent to solar farms (permanent pasture) representing the previous land use. These properties are thought to broadly capture complex plant-soil interactions that drive the functioning of terrestrial ecosystems and the delivery of numerous ecosystem services (Bardgett and Wardle 2010) and are commonly used as primary indicators of soil quality in national monitoring programmes (e.g. Emmett *et al* 2010).

2. Methods

2.1. Plant, soil, and climate data

We sampled 32 operational solar farms in England and Wales (figure 1) between June and September 2021 following standard protocols (Carvalho *et al* 2023). At each site, four replicate plots were randomly placed on land underneath solar panels ('under') and in between the rows of solar arrays ('gaps'; figure 1). In three sites (where permission was granted by landowners; figure 1), four additional plots were sampled in permanent pastures adjacent to these solar farms ('control'). Total plant cover (visual percentage estimation of vegetation cover within a quadrat as seen from above) and plant aboveground biomass (AGB) harvested at the soil surface with a pair of shears were sampled within 30 × 30 cm quadrats at each plot. Soils were sampled within the same quadrats to 10 cm depth and 5 cm diameter with a cylindrical metal corer. Four replicate soil samples were collected from each quadrat; three samples were homogenised in the laboratory for soil analyses and one sample was kept separate for bulk density measurements. Plant and soil properties directly linked to the delivery of multiple ecosystem services (e.g. biomass production, soil carbon storage, nutrient cycling) were estimated following standard published methods (table 1).

We adopted the soil classification system derived by Feeney *et al* (2023), based on the NATMAP vector dataset by Cranfield University (National Soil Resources Institute 2001), to characterise our sites by soil class. This soil classification captures key structural properties of soils, including texture, drainage, organic carbon/matter content, depth, flood risk, and the degree of modification from human activity (see supplementary material in Feeney *et al* 2023). Site-specific air temperature and rainfall data (annual averages for the 1991–2020 period provided on a 12 km British National Grid) were sourced from the UK's Met Office Climate Data Portal (https://climatedataportal.metoffice.gov.uk/).

2.2. Data analyses

All numerical analyses were performed in R 4.4.1 (R Core Team 2024). Plant and soil properties were either arcsine- (percentage variables converted to proportions; table 1) or $\log_{10}$- (continuous variables; table 1) transformed to reduce skewness and the effect of outliers prior to analyses, which largely followed the ten-step protocol outlined in Zuur *et al* (2009) to implement model selection in linear mixed modelling

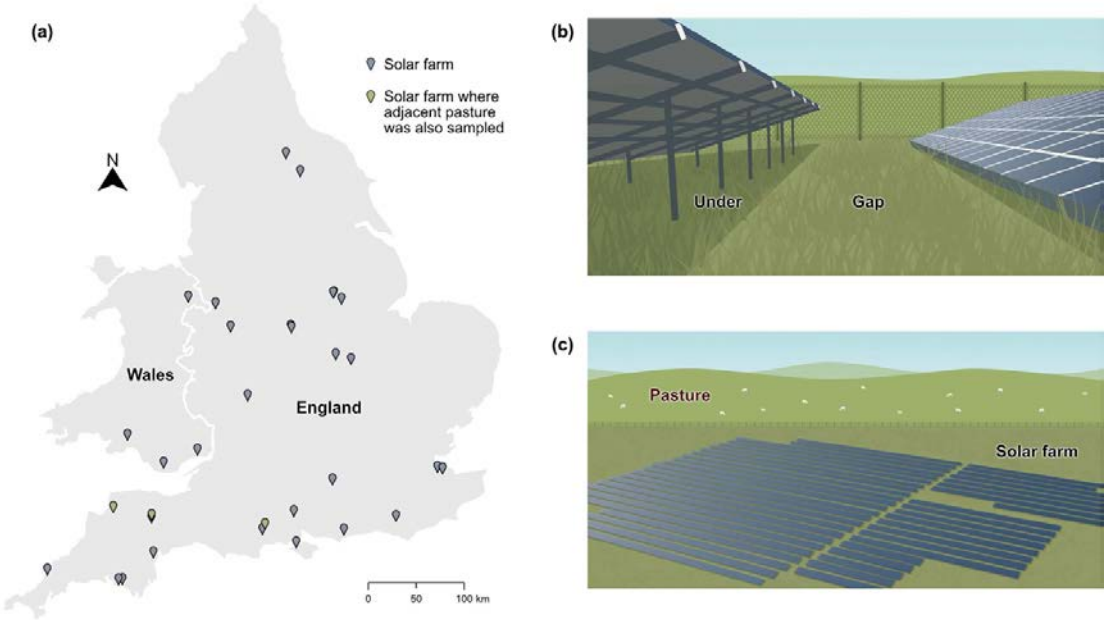

Figure 1. Location of the 32 solar farms sampled in England and Wales in summer 2021 (a) alongside visual representations of the treatments where plant and soil data were collected (b) and (c). Sites coloured in green denote the three solar farms where the adjacent pasture was sampled as a control treatment.

Table 1. Plant and soil properties measured on 32 solar farms in England and Wales in summer 2021. AGB = plant aboveground biomass, SOC = soil organic carbon, MAOM = mineral-associated organic matter, POM = particulate organic matter, N = nitrogen, P = phosphorus, BD = bulk density.

Property	Unit	Method	References
Plant cover	% cover	Visual plot-level estimation	Damgaard (2014)
AGB	Tonnes ha^{-1}	Destructive harvesting & oven-drying (60°C to constant mass)	Sala and Austin (2000)
SOC	% dry soil	Dry combustion (Vario EL Cube Elemental Analyser, Elementary, Stockport, UK) after acid (HCl) treatment	Harris *et al* (2001) Nayak *et al* (2019)
MAOM	% dry soil	Organic matter fractionation by size	Cotrufo *et al* (2019)
POM	% dry soil	Organic matter fractionation by size	Cotrufo *et al* (2019)
Total soil N	% dry soil	Dry combustion (Vario EL Cube Elemental Analyser, Elementary, Stockport, UK)	Emmett *et al* (2008)
Soil C/N ratio	NA	Soil organic carbon divided by total soil nitrogen	Emmett *et al* (2008)
Soil mineral N	mg N kg^{-1} dry soil	2 M KCl-extraction ($NH_4 + NO_3$ estimation in an Auto Analyser, Seal-Analytics©, Southampton, UK)	Emmett *et al* (2008)
Soil nitrate	Proportion of mineral N	2 M KCl-extraction (NO_3 estimation in an Auto Analyser, Seal-Analytics©, Southampton, UK)	Emmett *et al* (2008)
Soil Olsen P	mg P kg^{-1} dry soil	$NaHCO_3$-extraction (Auto Analyser, Seal-Analytics©, Southampton, UK)	Emmett *et al* (2008)
Soil BD	g dry soil cm^{-3}	Dried sample mass (110 °C for 24 h) over volume	Emmett *et al* (2008)
Soil pH	NA	Fresh soil pH in water (soil-water suspension)	Emmett *et al* (2008)

and address heterogeneity of variance and spatial correlation by testing different combinations of variance and auto-correlation structures.

We determined the effects of solar panels on plant and soil properties by testing the differences between the under and gap treatments ($n = 256$ per property; 32 sites × 4 replicates × 2 treatments) with linear mixed effects models fitted with the *nlme* package (Pinheiro and Bates 2023). Furthermore, we compared the two solar farm treatments (under and gap) to a control treatment (pasture outside the boundaries of the solar farm) for three sites where data were available ($n = 36$ per property; 3 sites × 4 replicates × 3 treatments).

In addition to *treatment*, the fixed effects included variables to account for local conditions (*soil class*), differences in climate between sites (*mean annual air temperature* and *rainfall*), and time since land use conversion (*age* of solar farms). The variable *site* was fitted as a random effect. The models that used data

from the three sites with adjacent pasture (control) only included *treatment, mean annual rainfall* and the *age* of solar farms, since *site* and *soil class* were colinear and *air temperature* showed low variability (coefficient of variation = 2.1%). Marginal means and pairwise differences between treatments were then estimated with the *emmeans* package (Lenth 2023) after back-transforming plant and soil properties to their original units.

Finally, for the three sites with data available for the adjacent pasture, we weighted the marginal means of the under and gap treatments to provide a solar farm weighted mean of plant and soil properties by accounting for the proportion of land within the under and gap treatments. Weighted means were calculated by summing the product of the weights (i.e. the proportions of the under and gap areas to the total solar farm area) times the marginal mean value of each variable and divided by the sum of the weights. The under and gap treatments accounted, on average, for 33% ± 0.06% (±1 SD) and 37% ± 0.09% (±1 SD) of the land between the three sites, respectively.

3. Results

3.1. Effects of solar panels on plant and soil properties

Areas under solar panels showed lower plant cover and AGB, lower soil carbon—when measured as soil organic carbon (SOC) and POM—and lower soil C/N ratio than areas in the gaps between solar arrays (figure 2). Soils under solar panels were more compacted and lower in total nitrogen than in gap areas, while (plant-available) mineral nitrogen and nitrate were higher under solar panels than in the gaps (figure 2). There were no statistical differences in MAOM, soil (plant-available) phosphorus (Olsen P), and soil pH between the two treatments (figure 2).

Older solar farms (ages ranged between 0.3 and 10.1 years old) tended to show higher plant cover, MAOM, POM, and soil nitrate than younger sites, though most differences were only marginally significant (table A1). Wetter sites showed higher plant AGB and higher soil carbon and nitrogen (measured in their different forms) than drier sites, while wetter soils were less compacted and lower in pH than drier soils (table A1). Measures of soil carbon and nitrogen varied among soil classes, but differences in air temperature between the sampled sites had no influence on the measured plant and soil properties (table A1).

3.2. Solar farms vs pasture

In the three sites where data for the adjacent pasture were available (figure 1), there were few statistical differences in plant and soil properties between gap areas and pastures (figure 3(b)), but areas under solar panels revealed higher soil compaction and lower plant cover, AGB, and POM than pastures (figure 3(a)). Solar farms generally showed higher soil (plant-available) nutrients than pastures, particularly Olsen P (figures 3(a) and (b)), though differences in mineral nitrogen and nitrate were only marginally significant (table A2). Rainfall had no influence on the results, but older sites showed marginally higher soil carbon and nitrogen (and marginally lower soil compaction) than younger sites (table A2).

When comparing solar farm weighted means (i.e. by accounting for the proportion of land under solar panels and in gap areas) to pasture means (table 2), SOC was slightly higher in solar farms than in pastures. In addition, the differences between the solar farm weighted means and the pastures were lower for plant cover, AGB, POM, and soil bulk density compared to the differences between the under areas and pasture (figure 3(a) and table 2).

4. Discussion

Our analyses are the first to demonstrate solar farm impacts on a suite of plant and soil properties across a range of sites and offer important insights into the effects of ground-mounted solar panels on plants and soils. Below, we discuss our results by grouping them into measures of plant (plant cover and AGB) and soil properties, including soil carbon and nitrogen (SOC, MAOM, POM, total nitrogen, and C/N ratio), soil (plant-available) nutrients (mineral nitrogen, nitrate, and Olsen P), and soil physiochemical properties (bulk density and pH).

4.1. Plant properties

Our findings, covering a range of solar farms with different design and site characteristics, indicate that plant cover and AGB are lower underneath solar panels than in gaps and pasture. However, effects may be context-dependent as plant cover has also been found to be unaltered by solar panels in some cases (Lambert *et al* 2021). Solar panels have been found to reduce plant photosynthetic rates and biomass by altering soil temperature and lowering receipts of photosynthetically active radiation (Vervloesem *et al* 2022) in temperate (Armstrong *et al* 2016) and Mediterranean (Lambert *et al* 2021, 2023) systems. Lambert *et al* (2023) found reduced plant biomass under solar panels to be due to higher allocation of resources to chlorophyll production to offset shading conditions, which in turn compromised resource allocation for biomass production of aboveground parts. However, the relationship between chlorophyll and biomass production is likely complex and highly variable between species (Paliwal *et al* 1986).

Management practices adopted by some operators may also have an impact on plant cover and biomass, including herbicide spraying to control weeds (often prominent under solar panels in summer; personal observation) and the sowing of low-statured

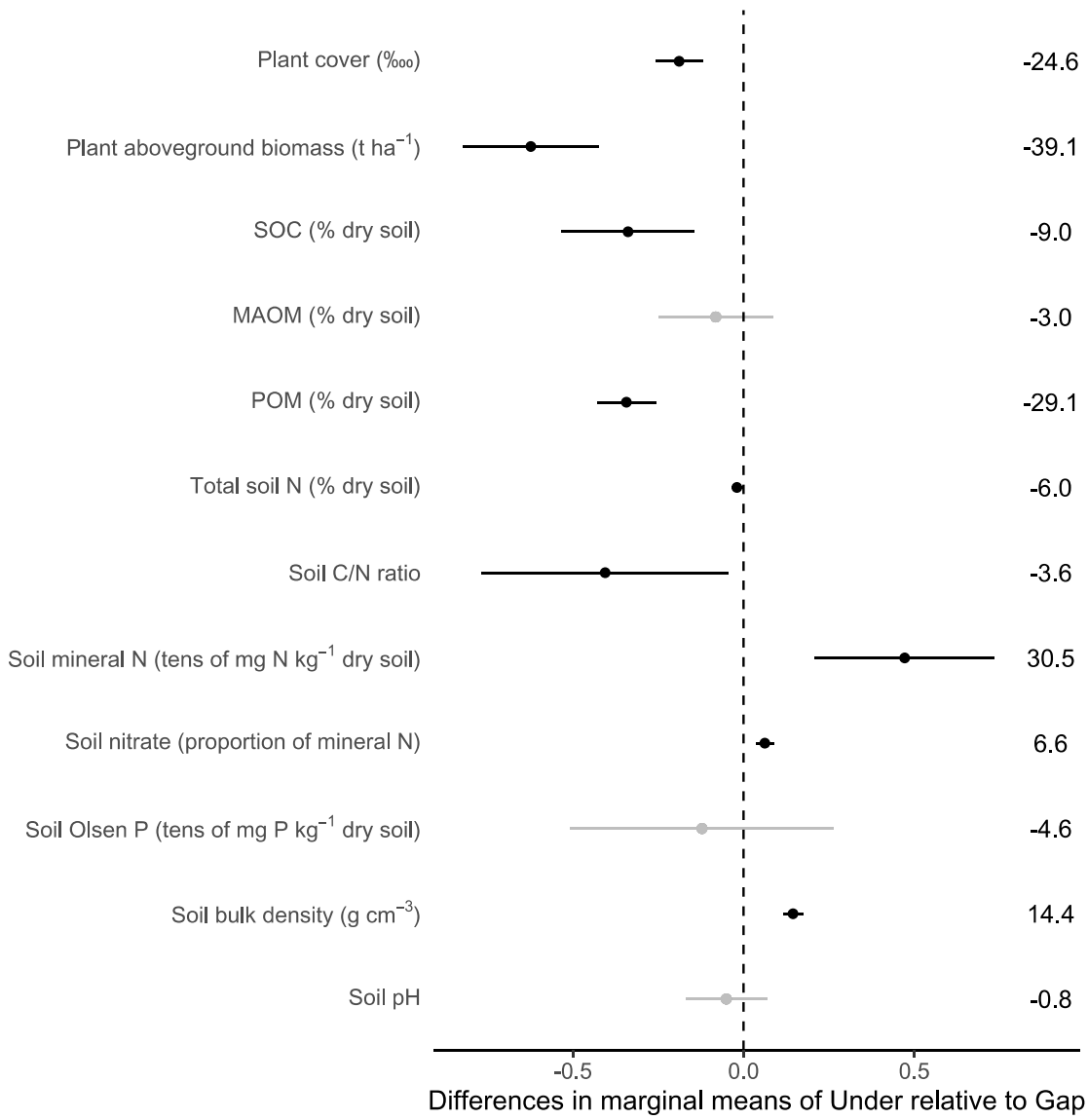

Figure 2. Pairwise differences in plant and soil properties between the under (land underneath solar panels) and gap (land between the rows of solar arrays) treatments. Error bars are 95% confidence intervals and circles depict differences between marginal means. Differences between treatment pairs are significant ($p < 0.05$) when the bars (highlighted black) do not overlap the vertical (dashed) zero line. If a difference is positive (i.e. to the right of the zero line), the under treatment has a higher marginal mean than the gap treatment (positive % difference shown on the right). If a difference is negative (i.e. to the left of the zero line), the under treatment has a lower marginal mean than the gap treatment (negative % difference shown on the right). Some results were scaled to 0 ± 1 by dividing them by 100 or 10 (see *y* axis labels). SOC = soil organic carbon, MAOM = mineral-associated organic matter, POM = particulate organic matter, N = nitrogen, P = phosphorus.

species to avoid shading of solar panels. The regular use of areas under solar panels for shelter by grazing sheep (personal observation on several sites) may also impact plant establishment and growth through heavy trampling.

The effect of solar panels on microclimate, coupled with land management decisions, also seem to influence plant community composition, diversity, and abundance, as well as the presence of indicator species (Armstrong *et al* 2016, Schindler *et al* 2018, Uldrijan *et al* 2021, 2022, Lambert *et al* 2022), by recruiting species tolerant to specific microclimatic, soil, and management conditions (Uldrijan *et al* 2021). This filtering may have implications for plant cover and AGB and affect ecosystem functioning (Hernandez *et al* 2014), trophic interactions (Uldrijan *et al* 2022), and the development of fire prone vegetation (Vaverková *et al* 2022).

4.2. Soil carbon and nitrogen

The lower soil carbon found for areas underneath solar panels compared to gap areas and pastures may be directly linked to the effects of solar panels on microclimate, solar radiation, and photosynthetic rates mentioned above. These effects can negatively impact plant establishment and growth, and reduce plant-derived carbon input to soils through altered plant tissue chemistry and litter quality and

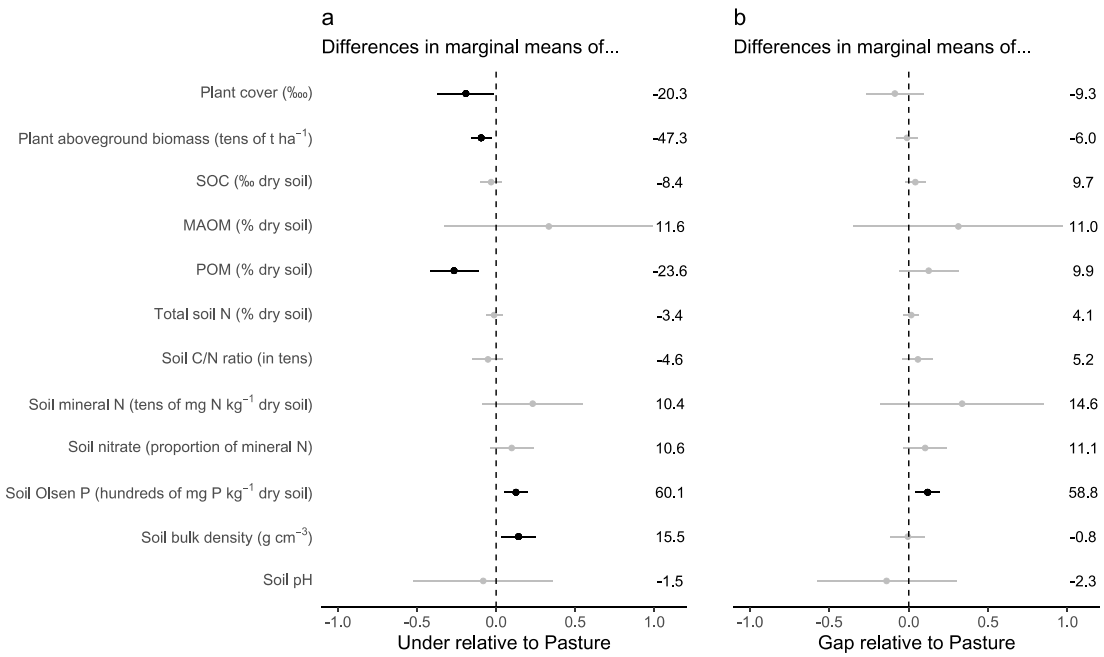

Figure 3. Pairwise differences in plant and soil properties between pasture (control treatment) and (a) the under treatment (land underneath solar panels) and (b) the gap treatment (land between the rows of solar arrays). Tukey adjustment was used to correct the p values for comparing three estimates (under, gap, and control), but only comparisons between under and pasture (a) and gap and pasture (b) are shown. Error bars are 95% confidence intervals and circles depict differences between marginal means. Differences between treatment pairs are significant ($p < 0.05$) when the bars (highlighted black) do not overlap the vertical (dashed) zero line. If a difference is positive (i.e. to the right of the zero line), the under (a) and gap (b) treatments showed a higher marginal mean than the pasture treatment (positive % difference shown on the right). If a difference is negative (i.e. to the left of the zero line), the under (a) and gap (b) treatments showed a lower marginal mean than the pasture treatment (negative % difference shown on the right). Some results were scaled to 0 ± 1 by dividing them by 100 or 10 (see y axis labels). SOC = soil organic carbon, MAOM = mineral-associated organic matter, POM = particulate organic matter, N = nitrogen, P = phosphorus.

Table 2. Mean differences in plant and soil properties between solar farms and pastures. Means are the marginal means of pairwise tests following mixed linear models fitted to the three sites where data were available for the adjacent pasture, but solar farm means were weighted by the proportion of land taken by the under and gap treatments. If a difference is negative in the final column, solar farms showed a lower mean than pastures.

Variable	Solar farm weighted mean	Pasture marginal mean	% Difference
Plant cover (%)	80.94	94.58	−14.4
Plant aboveground biomass (AGB) (t ha^{-1})	1.50	2.01	−25.2
Soil organic carbon (SOC) (%)	3.88	3.81	1.8
Mineral-associated organic matter (MAOM) (%)	2.84	2.52	11.3
Particulate organic matter (POM) (%)	1.07	1.13	−5.2
Total soil nitrogen (%)	0.38	0.38	0.6
Soil C/N ratio	10.97	10.90	0.6
Soil mineral nitrogen (mg kg^{-1})	22.78	19.91	12.6
Soil nitrate (proportion of mineral nitrogen)	0.92	0.82	10.9
Soil (plant-available) phosphorus (Olsen P) (mg kg^{-1})	20.54	8.34	59.4
Soil bulk density (g cm^{-3})	0.83	0.77	7.7
Soil pH	5.94	6.06	−1.9

quantity (Gill *et al* 2002). Similarly, the lower total soil nitrogen recorded underneath solar panels compared to gap areas may be due to relatively low levels of plant-soil feedbacks (e.g. nitrogen fixation through N-fixing bacteria; van der Putten *et al* 2013) and nutrient cycling under reduced levels of plant-derived organic matter input and microbial activity (Lambert *et al* 2023), as recorded in soils under solar panels elsewhere (Choi *et al* 2020, Lambert *et al* 2021, Moscatelli *et al* 2022). In addition, vegetation removal and soil disturbance due to tillage, levelling, trenching works, machinery compaction, and/or topsoil removal before or during solar farm construction may increase erosion and mineralisation rates of organic

matter and also result in reduced SOC (Quinton *et al* 2010, Gregory *et al* 2015) and nitrogen (Lambert *et al* 2021, Moscatelli *et al* 2022) content.

The lower POM observed underneath solar panels compared to gaps and pasture could be a direct result of lower plant biomass, since POM is mostly plant-derived, fast-cycling, and relatively vulnerable to disturbance (Cotrufo *et al* 2019). Reductions in POM may have important implications for long-term changes in SOC considering temperate grasslands can store significant fractions of organic carbon in POM pools (Denef *et al* 2013), making construction and management practices that reduce soil disturbance and maximise carbon input to soils particularly important. Lower POM can also have consequences for soil aggregate stability (Zech *et al* 2022) and negatively impact soil infiltration and erosion rates (Abu-Hamdeh *et al* 2006). In addition, despite being predominantly of microbial origin and relatively slow-cycling, MAOM can receive substantial carbon contributions from plant-derived organic matter and be closely related to short-term SOC cycling (Yu *et al* 2022). Therefore, despite no differences in MAOM between treatments found here, MAOM could be negatively affected over time under solar panels if plant-derived carbon inputs remain low. Moreover, MAOM tends to rapidly saturate under organic fertilisation (Stewart *et al* 2007, Just *et al* 2023), after which the continuous sequestration and storage of soil carbon is only possible through additional POM accrual (Cotrufo *et al* 2019). This could have consequences for long-term soil carbon storage under solar panels, since MAOM is a more persistent form of carbon than POM. Reductions in POM and MAOM could also have consequences for microbial growth and the soil food web by affecting supply of labile carbon and nutrients to plants and microbiota (Lavallee *et al* 2020), as evidenced elsewhere by lower microbiological activity and nutrient cycling under solar panels due to low soil organic matter (Lambert *et al* 2021, 2023, Moscatelli *et al* 2022). Given the potential for temperate grasslands to uptake carbon (Ostle *et al* 2009), there is ample evidence of the importance of land management on soil carbon (Carvalho and Armstrong 2021), and these should be carefully considered in relation to local conditions.

4.3. Soil (plant-available) nutrients

Given solar farms are rarely fertilised, the persistence of plant-available nutrients (nitrogen and phosphorus) in solar farm soils after construction, particularly underneath solar panels, may be a legacy of previous land fertilisation regimes under agricultural production since declines in inorganic nutrients may take several years to occur after cessation of agricultural activities (Parkhurst *et al* 2022a, 2022b), especially if they are not continually removed through harvesting (McLauchlan 2006). Vervloesem *et al* (2022) attributed higher nutrient content in soils underneath solar panels to their relatively low exposure to sun and rain compared to gap areas that could result in nutrient accumulation over time due to reduced leaching. In addition, the microbial carbon deficiency commonly found under solar panels (Lambert *et al* 2021, 2023) triggered by relatively low plant carbon inputs (rhizodeposition) may be driving microbial targeting of MAOM carbon pools with relatively low C/N ratio to result in excess nitrogen release into the soil via nitrogen mineralisation (Mooshammer *et al* 2014). These effects could lead to negative outcomes for biodiversity and ecosystem functioning long after land use change given the well-documented relationships between soil nutrients and plant species richness and abundance (Isbell *et al* 2019).

Despite the differences in soil nutrients among treatments described above, comparisons between sites under varying conditions and of different ages are difficult since the legacy of agricultural effects on soil properties can be highly variable and dependent on several factors, including time since land use change, post-agricultural management, climate, and mineralogy (McLauchlan 2006).

4.4. Soil physiochemical properties

Compaction of agricultural soils is typically associated with regular trafficking of agricultural machinery or the presence of grazing livestock, and its effects have been well documented (Gregory *et al* 2015), including increased risk of flooding and soil erosion (Batey 2009) and reduced biodiversity (Roovers *et al* 2004). The higher soil compaction under solar panels compared to gap areas and pastures is likely the result of a mixed legacy of previous (and current) agricultural practices (notably livestock grazing) and the use of heavy machinery during construction. Soils in the gaps showed similar levels of compaction to pasture, possibly due to largely successful revegetation efforts after solar farm construction and relatively low levels of disturbance during solar farm operation. In contrast, low levels of vegetation establishment and growth under solar panels may be directly related to high soil compaction due to reduced plant root penetration and water cycling that would help increase soil porosity and aeration, and reduce compaction (Correa *et al* 2019).

There were no statistical differences in soil pH between treatments, but soils under solar panels were slightly more acidic than in gap areas and pastures. Previous research found lower soil pH under solar panels compared to other land use types (Vervloesem *et al* 2022), which was attributed to low soil carbon and nitrogen (Aciego Pietri and Brookes, 2008, Chen *et al* 2016) and high (plant-available) nutrient concentrations (Chen *et al* 2015) under solar panels affecting soil fauna and the concentration of mineral cations. Soil pH will vary considerably from site

to site though depending on several factors, including soil type and texture, climate, topography, mineralogy, and water availability (Slessarev *et al* 2016).

5. Implications

The results presented here showed that, across a range of solar farms within temperate agricultural systems, the most marked impact of ground-mounted solar panels is on vegetation, with cascading effects on soil properties. This indicates that solar farms in temperate systems with a past agricultural legacy should be actively managed (e.g. by seeding diverse native species mixtures and maintaining structured habitats) to maximise delivery of plant- and soil-related ecosystem services. This is particularly true for biomass production and long-term soil carbon storage and sequestration, given the observed effects of solar panels on vegetation and their consequences for soil properties (e.g. soils being deprived of plant carbon inputs due to relatively low plant biomass under solar panels). However, our results suggest that past biotic and abiotic agricultural legacies can be overcome to allow solar farms to deliver environmental benefits other than low carbon electricity, given plant and soil properties in the gaps between solar arrays were generally similar to control conditions, suggesting no deterioration of ecosystem functioning in solar farms if converted from agricultural land. In fact, plant cover and soil carbon showed signs of improvement as solar farms aged (tables A1 and A2), meaning plant- and soil-related ecosystem services could improve over time if solar farms were managed accordingly (Randle-Boggis *et al* 2020) and offered the right policy incentives (Carvalho *et al* 2024b).

Solar farms can be designed and managed to deliver positive plant and soil outcomes. Regarding design, increasing the height of solar panels over the ground to offset the negative effects of shading and changes to microclimate on plant productivity, or increasing the proportion of gap areas (and other areas within solar farms such as margins) to favour plant development and consequently benefit soils through enhanced carbon inputs would be beneficial. Areas under solar panels account for approximately 39% of land in an average solar farm in the UK (but it could be as high as 70% in some cases; Blaydes, unpublished digitised solar farm data), offering scope to manage the remainder to deliver net positive outcomes for nature. In fact, differences in plant and soil properties between solar farms and pastures were lower than differences between under and pasture when accounting for the proportion of land in the different treatments (under and gap), while soil carbon was slightly higher in solar farms than in pastures on average (table 2), even if margins were not considered in this study. These results suggest solar farms can deliver net environmental gains across the site if enough area is set-aside for conservation away from solar arrays. However, increasing the proportion of land not over sailed by solar panels may result in higher land take for solar farms, meaning overall outcomes will depend on the type of land use being converted.

Finding management solutions to enhance vegetative cover under solar panels in temperate systems will be challenging, given the relative novelty of this type of land use and the fact plant and soil responses to active land management are highly dependent on local conditions. Management options may include the use of low impact machinery during construction to reduce soil compaction, the reduction in soil (plant-available) nutrients to promote species diversity (Isbell *et al* 2013, Midolo *et al* 2019), the regular monitoring of soil pH to formulate soil remediation measures if needed (Neina 2019), the sowing of generic all-purpose seed mixes that can establish on a range of soils and contain shade-tolerate species, and the use of conservation cutting and grazing to promote structured and diverse habitats to benefit wildlife. Frequent monitoring using standardised approaches (Carvalho *et al* 2023) will ensure the delivery of land management objectives and the collection of data that are comparable across sites. This will be key in guaranteeing the long-term provision of ecosystem services and in offering a broad picture of the ecosystem effects of this rapidly expanding novel land use.

6. Conclusions

Solar energy, especially in the form of ground-mounted solar farms, is set to play an important role in decarbonising electricity supplies worldwide. To address both the climate and biodiversity crises, the effects of ground-mounted solar panels on plants and soils must be considered before, during, and after solar farm development and contextualised to local conditions. In addition, the overall impact of a solar farm must be appropriately scaled to account for net environmental change across the site after land development given contrasting effects experienced by areas under solar panels to those in the gaps between solar arrays.

Given the relative youth of solar farms and their anticipated growth, it is critical that ecosystem responses to solar farm development and management are continually monitored to maximise positive biodiversity outcomes. The development of solar farms on agricultural land may lead to benefits for some ecosystem services over time (considering time lags in soil response to land use change), but developing ways to address the legacy of previous agricultural land use and enhancing plant cover under solar panels should be the focus of future research.

Other explanatory variables not included here (e.g. previous land use, land management, gap width, solar panel height and angle) should be considered

in upcoming studies as they may also drive plant and soil responses to solar farm development and can be altered to maximise positive biodiversity outcomes. In addition, the expected growth in solar farms may be accompanied by integrated battery storage facilities, introducing other environmental impacts (Simpa *et al* 2024). Consequently, the effects of battery storage facilities on soils should be considered in future research as they become increasingly more common.

Plant and soil properties may offer foundational indicators to investigate the impacts of solar farms on ecosystem services, but better understanding of the potential effects of solar farms on wider biodiversity (e.g. invertebrates, birds, mammals) is also needed to develop ways to manage solar farms that can benefit nature recovery in the fullest sense.

Data availability statement

The data cannot be made publicly available upon publication because they are owned by a third party and the terms of use prevent public distribution. The data that support the findings of this study are available upon reasonable request from the authors.

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Author contributions

[redacted] performed laboratory work. [redacted] produced the map and graphics in figure 1. [redacted] advised on the use of soil classes and performed data selection. H[redacted] analysed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for submission.

Conflict of interest

[redacted] was co-funded by Clarkson & Woods Ltd, [redacted] is employed by Clarkson & Woods Ltd, H[redacted] was co-funded by Low Carbon Investment Management Ltd, [redacted] is Managing Director of Clarkson & Woods Ltd. [redacted] is currently employed by the Environment Agency; the views expressed are hers and those of the authors and are not formal positions of the Environment Agency.

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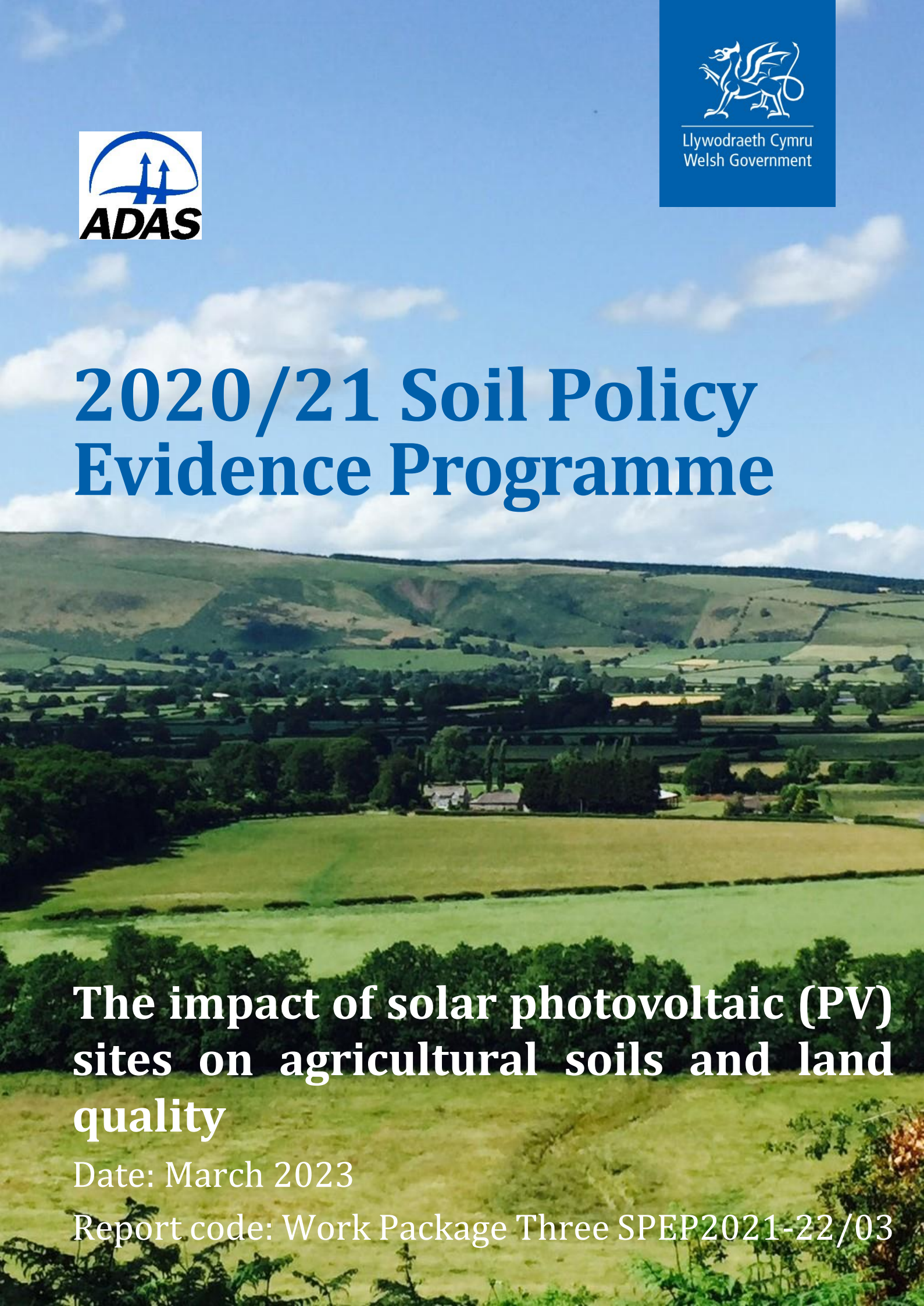


Llywodraeth Cymru
Welsh Government

ADAS

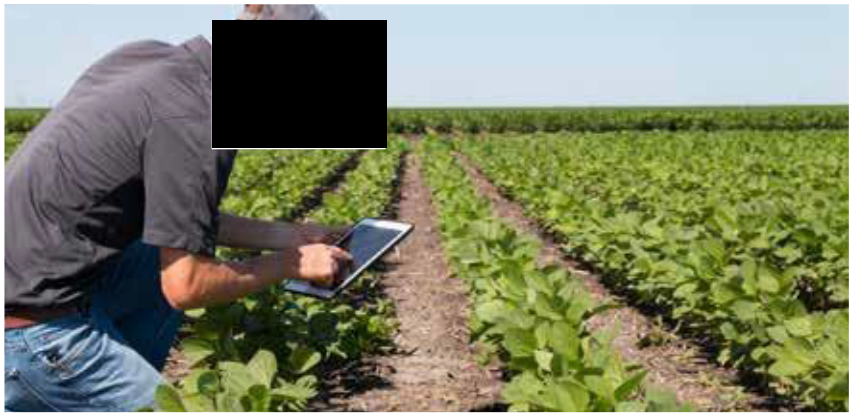
2020/21 Soil Policy Evidence Programme

The impact of solar photovoltaic (PV) sites on agricultural soils and land quality

Date: March 2023

Report code: Work Package Three SPEP2021-22/03

Welsh Government



The impact of solar photovoltaic (PV) sites on agricultural soils and land

Work Package Three: Review of Impacts

March 2023

ADAS

ADAS GENERAL NOTES

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EXECUTIVE SUMMARY

This report is part of an evidence-based assessment of the impact of solar photovoltaic (PV) sites on agricultural land and soil. The work, under the Welsh Government's Soil Policy Evidence Programme SPEP 2021-22/03, is to inform Welsh Government and Natural England specialists when dealing with solar photovoltaic (PV) planning applications.

The impacts on Best and Most Versatile[1&2] (BMV) agricultural land from the construction, operational and decommissioning phases are reviewed, based on the findings of the earlier literature review (WP1), best practice and extensive experience of land restoration. The main impact of the three phases of development is deep soil compaction resulting in the loss of versatility of Best and Most Versatile agricultural land and in wetter parts of England and Wales the loss of Best and Most Versatile agricultural land. An assessment is made of the reversibility of the impacts. Soil compaction results mainly from trafficking and alleviation is reported to depths of 45cm. It can take many years for soils to recover from compaction and compaction may be permanent. Runoff from panels can result in rivulets, which can lead to soil loss by erosion.

The benefits of topsoil carbon capture and soil structural improvements are reported for grassland. Research on the impact of solar PV panels on microclimate beneath panels highlights the changes in temperature on vegetation growth.

The decommissioning phase involves the removal of the solar PV site infrastructure. The issues of 'pile pull out' are considered, including corrosion and fracture of the piles.

Good soil handling conditions may mitigate the threats to soil and land. Appropriate planning with a quality soil resource and management plan is essential at the planning application stage to ensure that conditions, as part of the planning process, are relevant and focussed on the restoration of the land to agriculture.

[1] Planning Policy Wales Paragraphs 3.58-3.59 Edition 11 February 2021 and National Planning Policy Framework

[2] Land classified as Grade 1, 2 and 3a. MAFF Agricultural Land Classification Guidelines. 1988

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1 BACKGROUND

This report is part of an evidence-based assessment of the impact of solar photovoltaic (PV) sites on Best and Most Versatile (BMV) agricultural land and associated soils. The work, under the Welsh Government's Soil Policy Evidence Programme SPEP 2021-22/03, is to inform Welsh Government and Natural England specialists when dealing with solar photovoltaic (PV) planning applications.

A detailed search of published research and industry experience has been undertaken to inform this report. The search concentrated on the impacts of solar PV sites on agricultural land and soils within the UK and internationally. There have been few studies of solar PV sites which have a focus on the impacts on agricultural land and soils. This is largely because solar PV sites are recent developments but also because in the early years sites were located on brownfield land or poorer quality agricultural land. The importance of achieving successful restoration of solar PV sites has increased in significance as the number, size and operational time frame of solar PV sites on BMV agricultural land has increased.

An overview study of the industry has been undertaken and informs this report. The distribution of solar irradiation (Huld et al,2019) across the UK ranges from approximately 900-1350kWh/m^2 per year, with the highest resource available in the South West. There has been a trend (BEIS, 2021) towards larger schemes (up to 50 MW and a typical land take of 50ha to 80ha), because of the ceiling for schemes dealt under the Town and Country Planning Act in England. There has also been a move to 'super large' solar PV schemes, generally over 300ha in size. Published sources of guidance for solar developers identified are limited and include several BRE publications (2013, 2014).

Solar Energy UK have prepared a 'best practice guide' (https://solarenergyuk.org/wp-content/uploads/2022/05/NCBPG-Solar-Energy-UK-Report-web.pdf), with much focus on the benefits for ecology and biodiversity and little consideration of the impact on soil. A virtual workshop was held on 2nd September 2021 with Welsh Government, Natural England and invited interested parties.

This report reviews the potential impacts to soil and land associated with solar PV site developments at the commissioning and decommissioning phases. The potential effects on soils during the operational phase of the site are considered and the physical reversion from low-maintenance grass to other agricultural uses typically associated with BMV agricultural land and non BMV agricultural land is undertaken.

This report follows the Technical Specification received from Welsh Government and the layout closely follows the points in the brief (Appendix 1).

ADAS gratefully received evidence from the trade body Solar Energy UK to inform this project and details of the evidence provided over December 2021 – January 2022 is provided in Appendix 2.

2 CONSTRUCTION, OPERATION AND DECOMISSIONING

2.1 Overview of Construction phase

At the time of the submission of the planning application, the solar PV developer will have prepared site outline plans showing details of all aspects of the proposed scheme. Each site is designed taking into account the site's technical assessment, landowner negotiation and grid connection. The solar PV site will typically include some key activities resulting in effects on soil and land, including:

1. Site levelling
2. Construction compound (either for operational life or the temporary during construction phase)
3. Site fencing and security
4. Access road/tracks
5. High voltage cabling
6. Low voltage cabling
7. String cabling
8. Earthing
9. Steel framing mounts and PV panels
10. Piles
11. Inverters and container bases
12. Substation

2.2 Overview of Operational Phase

Solar PV sites are usually unmanned once commissioned. Regular visits may be planned by operations and maintenance staff to undertake monitoring and site maintenance. Typical activities include grass cutting, if grazing does not keep the grass at the optimum height, management of landscaping works and panel washing. The visits will generally require a 4x4 vehicle. Grass on the site is often grazed by sheep, particularly in Wales.

2.3 Overview of Decommissioning Phase

Outline plans stating that decommissioning will be undertaken at the end of the operational life of the development are generally included in the planning application stage. A condition of planning permission is that a more detailed plan, usually about 6 months before the end of the operational life, is submitted to the planning authority. Decommissioning may be

triggered by the end of the operational life of the development or by economic reasons or abandonment (Stantec, 2020).

Typical activities at the decommissioning phase may include:

1. Access roads may need to be reinforced to be able to carry traffic involved in the decommissioning phase
2. De-energise solar arrays
3. Dismantle panels and racking
4. Removal of piles from soil and reinstatement of soil into voids
5. Removal of frames and internal components
6. Removal of structural foundations and backfill sites
7. Removal of inverter stations and foundations
8. Removal of electrical cables and conduits
9. Removal of access and internal roads
10. Removal of substation.

2.4 Impacts on soil and land

2.4.1 Construction phase - overview

The construction of the solar PV site involves operations that necessarily impact on the soil and land. All activities at the construction phase involve trafficking by plant/machinery across the whole site, possibly following access tracks on parts of the site. Examples of the equipment used include excavators and dumper trucks for soil removal and storage, trenching machinery, piling rig and dumper trucks for the transportation of cabling, piles, mounts and panels on site.

The removal of a depth of soil is necessary to prepare the site compound, access roads and site tracks (where aggregate and geo textile membrane are used) and bases for inverters and substations. Site fencing, usually 2m high deer or security fencing, is placed around the site perimeter. Wooden supporting posts are often used, which do not require concrete foundations except at the corners and gateways. With typical spacings of 2.4m to 3m there are approximately 300-416 posts per 1000m run of fencing. The length of fencing varies according to the site layout and each post may be sunk at a depth of up to 1m below ground level. Metal fencing may be used where there is a risk of theft and will require concreting at every footing, which will be spaced at approximately 2m giving 500 posts per 1000m run.

2.4.2 Construction phase - piling

The PV panels are placed on frames which are attached to supporting piles. Most sites use H or I beams, driven into the ground by a piling rig (with a vibrating plate) to a depth of approximately 1.4m to 2m. The beams displace a volume of soil about equal to the volume of the pile. H beam piles are described as 'non-displacement', but soil is displaced as a soil plug forms between the flanges and moves down the pile as it is driven (Ahlvin et al, 1988).

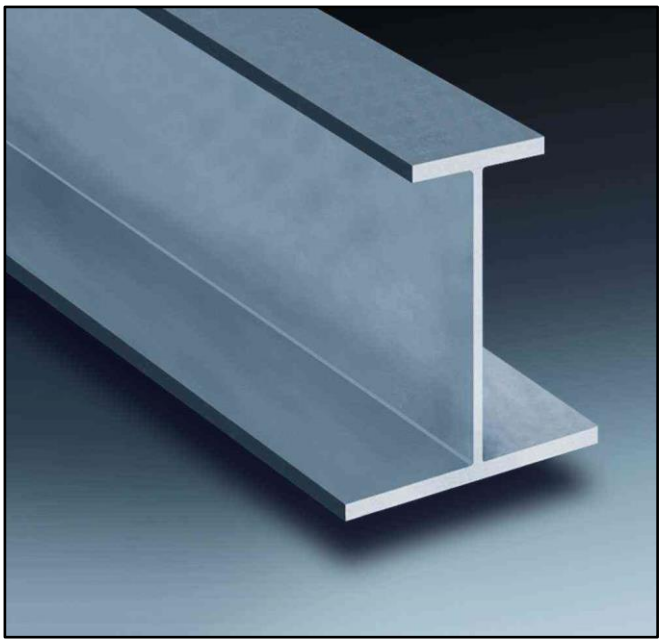

Figure 1: H beam (Sinosources)

H beams have wider flanges than I beams, which have tapered edges. In sandy soils the displaced volume results in compaction of the soil surrounding the pile. In clay soils displacement piles create high stresses in the soil. There is no spoil on the surface.

Helical piles or screws are cylindrical posts with a helix near the bottom of the post and the helix part resists being pulled out by creating a cone of soil above it. Helical piles are installed by digging an initial guiding hole and using a skid steer vehicle with a rotating attachment to spin the pile into place. Helical piles have a smaller surface and will embed with minimal soil disturbance.

Figure 2: Helical beams

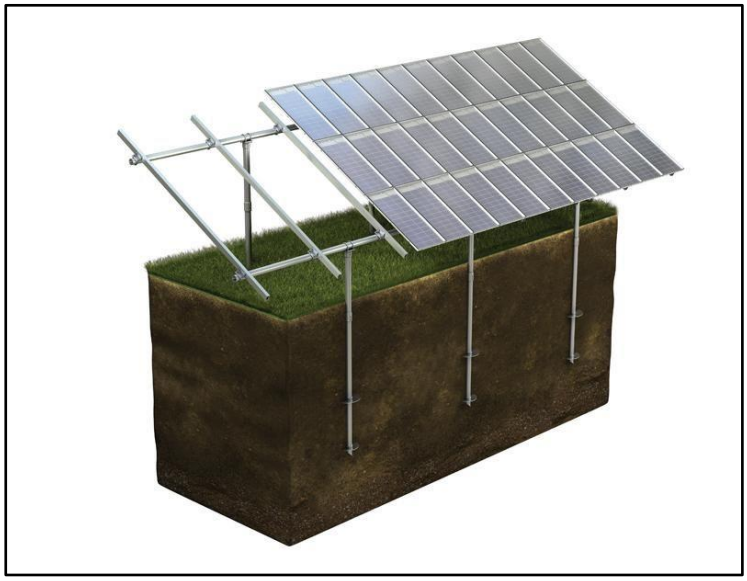

Figure 3 Helical piles at depth (Goliathtechpro.com)

H beams are used on larger scale developments as they have a stronger load bearing and require fewer penetrations per rack compared to helical anchors or ground screws.

The number of piles required is determined by the site layout. One case study in WP2 gave the number of piles as 492 piles per ha. Many planning applications for solar PV sites usually include an elevation plan of the solar panel and give the number of PV panels as an illustration, but not the number of piles required.

Ballasted systems provide a non-penetrating foundation to support solar PV frames. The concrete bases can be used on land fill sites or where deep penetration from H beams may damage archaeological features.

2.4.3 Construction phase – soil movement

The development of solar PV sites requires the excavation of soils associated with construction compounds, access roads and trenching for cables. Soil removal is usually undertaken for construction of the site compound and access roads/tracks, where a geo-textile membrane may be placed over the subsoil and covered with a surface layer of aggregate. The depth of soil stripped for the compound and for the foundation of bases for inverters and substations should be determined by an assessment of soil resources on site. A review of the case studies (WP 2a) showed removal of soil to depths of up to 30cm i.e. typically topsoil, but excavation to this depth could mix in some subsoil if it is not stripped separately. Trenches created by a trenching machinery will require the removal of soil to a depth of typically up to 1.2m (i.e. a layer of topsoil and subsoil and on some sites overburden) and a width of up to 0.75m. The cables are placed in sand with a suitable backfill placed over. The amount of trenching and cabling is site specific, and one case (Estuary Farm WP2) reported a cabling requirement of approximately 2km on the site.

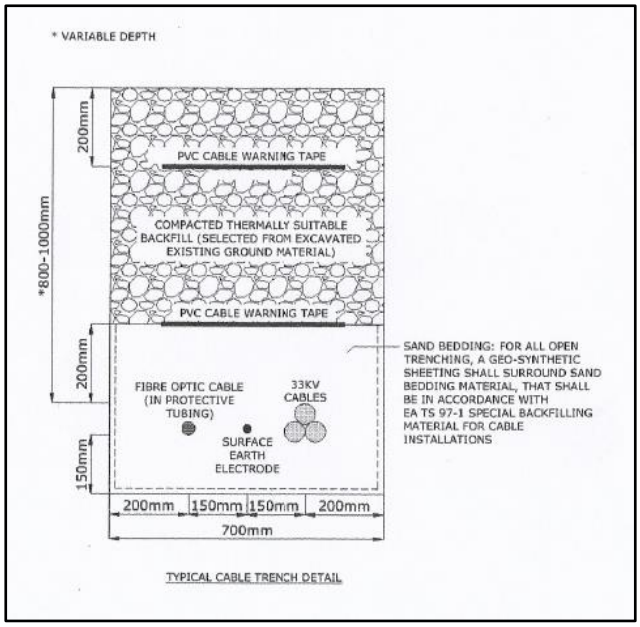

Figure 5: Typical cabling trench details

Site levelling works may be required depending on the site contours and on sites where tilting PV panels are used. Such an engineering operation will disturb the topsoil and it may be that some fill is required on site.

Damage to field drainage systems can occur as piles are driven into the ground, resulting in localised or widespread wet areas within the site.

2.4.4 Operational Phase

During the operational life of a solar PV site there is likely to be minimal disturbance of the site. The wooden posts of deer/security fencing will require replacing through the lifetime of the development due to rot. Frequency of replacement will be greatest in wet or exposed sites. Excavation of the post hole will be required and then re-compaction of the soil leading to localised compaction around the hole and along the access track.

Land between and underneath the PV panels is often grazed by sheep and where there are high numbers of sheep a solid compaction layer 2 cm to 6 cm over a wide area may result (Defra, 2021). There is likely to be some instances of run-off from the solar panels, which could result in the compaction of soils at the base of the panels (Choi et al,2020). Over time rivulets can form along the trailing edge of the panel with potential risk of soil erosion creating rills and gullies across the site. The sand bed could act as a drain, especially on heavy textured soils, leading to drainage discharges or wet patches at the down slope end of each trench.

Figure 6: Channels created by panel runoff within 12 months of site operation commencing

2.4.5 Decommissioning Phase

When the decommissioning phase is triggered at the end of the operational life of the solar PV site, operations to remove the physical infrastructure commence. Access roads and tracks may require reinforcing to be of a standard suitable for heavy machinery. Trafficking will again occur across the site on and off the site tracks as panels, frames and inverter cabins and substations are removed. Cabling may be removed from trenches and string cabling will be dismantled. Access roads, and construction compounds will have aggregate and the geo-textile membranes removed. Where the inverter cabins have been placed on an aggregate base or concrete plinth then this should be removed.

The extraction of the piles is likely to be more problematical than the initial installation (per. comm. P. Woodfield, Technik GS). Pile extraction is undertaken typically with a 13-ton excavator and vibrating pile driver attachment, which removes one beam and then tracks to the next one (per. comm. I. Woolley, Twig Group). A vibrating plate shakes the soil at removal stage, to ensure that the soil stays in place with little disturbance as the H beam is lifted out of the ground, this reduces the risk of soil attaching to the H beam and resulting in a larger area lifting. The volume occupied by the steel beam is the theoretical void. Where there are granular soils e.g. sands and gravel, the soil will fall into the void to occupy the space. The soils do this through a combination of gravity, flow if below the water table and the likely vibration effects while withdrawing the piles (per. comm. M. Wheeler, Binnies).

In clay soils there will be softening and swelling to close the void over time partially or wholly. Plugging can occur in clay soils where the soil may stick to the pile and be withdrawn with the pile, in effect pulling out a solid unit defined by the flanges and width of the pile. The volume of the soil pulled out is greater than in sandy soils and can produce a local ground settlement as soil swells or collapses to fill the void unless measures are taken to fill the void at the time of withdrawal. The clay or soil adhering to the pile can be cleaned off and returned to the hole and then the void is minimal as bulking takes up part of the volume, but this may mix topsoil and subsoil unless carefully managed. Widespread ground settlement is unlikely to occur, although there may be localised ground surface settlement at the point of the pile extraction. It is expected that any localised ground surface settlement would be removed at the time of cultivations on the site. There is no known reported experience of pile pull out within the solar industry in the UK. A study of civil structures in Japan, where the ground is 'soft' and many structures use pile foundations, reported that 'filling' the void was effective in reducing ground subsidence and that the 'filler' must suit the ground conditions (Inazumi et al, 2017). At this stage in the life of the ground-mounted solar PV industry, the impact of pile pull-out on agricultural land and soil is a 'grey' area with few conclusions having been drawn to date.

2.5 Risks to agricultural land quality

During the construction and decommissioning phases there will be soil movement and soil handling on site. During the commissioning, operational and decommissioning phases there will be trafficking by a range of machinery, including dozer, tracked excavator, wheeled backhoe loader, hydraulic hammer rig and rotary bored piling rig, vibrating plates, which can result in soil compaction. The main cause of compaction is the compressive forces applied to the soil from the wheels or tracks of machinery. Hakansson (1985) found that an axle load of 10 tonnes increased soil bulk density to a depth of 50 cm. Compaction may be very persistent in the subsoil and possibly permanent (Hakansson et al 1988). Where there is '*industrial compaction'* the depth of compaction can extend to depths of 1m (Spoor, 2006) and may persist for up to 30 years (Batey, 2009).

Low ground pressure tyres and tracked machinery may reduce the impact of compaction. Tracked vehicles can reduce rut depth by up to 40%, compared to extra wide or soft tyre options (Bygden etc al, 2003). The weight on tracked machinery is concentrated beneath the idlers and the bogies (the wheels within the tracks).

Field identification of soil compaction includes evidence of waterlogging on the surface or in subsurface horizons, an increase in soil strength or bulk density, low visible porosity, poor structural conditions, soil colour and rooting pattern (Batey, 2009).

Techniques for loosening compacted soils to depths of about 45cm are established, but at lower depths correcting problems may not be effective and economic and engineering equipment is required.

As well as the forces applied to the soil, the soil water content and bearing capacity are critical at the time the pressure is applied – this is true for both the instance of compaction and the alleviation of compaction.

Soil compaction can occur and be unrelated to mechanical forces, for example finely aggregated soil 'tumbling' down from the surface when cracks are open and wide (Batey,2009). There is potential for soil falling into the voids created when piles (e.g. H-beams) are removed.

The impact of soil compaction is well documented (Batey, 2009) and crop growth, yield and quality may be adversely affected. There are also wider environmental implications relating to water and air quality.

The extent of trafficking and soil disturbance can cover a substantial proportion of a solar PV site. Satellite imagery of three solar schemes is included in Appendix 3 to this report. This imagery shows:

- 1) Hunstpill Level Solar Farm, Sedgemoor District – pre-construction
- 2) Hunstpill Level Solar Farm, Sedgemoor District – during-construction
- 3) Lamby Way Solar Farm, Cardiff – pre-construction
- 4) Lamby Way Solar Farm, Cardiff – early-construction
- 5) Lamby Way Solar Farm, Cardiff – mid-construction
- 6) Lamby Way Solar Farm, Cardiff – post-construction
- 7) Afon Llan Solar Farm, Swansea – pre-construction
- 8) Afon Llan Solar Farm, Swansea – during construction

The imagery is taken from Google Earth Pro (historical imagery), Google Earth and Bing Aerial.

A number of developers have published videos on the YouTube.com showing phases of solar farm construction in the UK. Some videos appear to show construction during good ground conditions, with suitable access tracks constructed to support the field work. Other videos, however, appear to show no consideration for topsoil preservation and work proceeding during very wet conditions, resulting in wheel ruts, surface water ponding and slurrified soil in places. Extracts from two of these videos are provided in Appendix 4. Whilst care must be taken when drawing conclusions from such limited evidence from any given site, the videos give an idea of the soil disturbance that can occur during a solar PV site construction.

On all sites there is the potential impact on soils from the spillage or leakage of fuel and oil. Contaminants only affect agricultural land classification grading where they have or are likely to have a detrimental long-term effect on the physical condition of the soil (MAFF,1988), the yield, cropping and the stocking rates. It is likely that the impact on solar PV sites will be minimal, as bio-oils are widely used and incidents managed through control of contaminants and action.

The supporting information for solar PV sites indicates that galvanised aluminium or steel posts are used to support the frame. Galvanising involves a coating of zinc with thickness ranging from 0.3mm to 3.5mm. The impact on soil and land from the zinc coating is unknown. Defra's code for using sewage sludge (Defra,2018) gives thresholds for zinc in soils of 200 – 300mg/kg; these levels are very unlikely to be achieved from the presence of piles in the soil, although the base level of zinc could influence the threshold. Research on agricultural land has shown that zinc in soils diminishes biological activity (Moffett et al, 2003).

The maintenance of on-site ditches will be key to ensuring that surface water is managed on site. Should maintenance not be undertaken, there is a potential impact of flooding on land. Many solar PV site planning applications consider surface run-off within a management strategy.

3 AGRICULTURAL LAND QUALITY

This section of the report looks specifically at agricultural land, and the risk of residual impacts of solar PV sites on agricultural land quality and Best and Most Versatile (BMV) agricultural land.

The Agricultural Land Classification (ALC) system is used in England and Wales to determine agricultural land quality. The ALC system provides '*a framework for classifying land according to the extent to which its physical or chemical characteristics impose long-term limitations on agricultural use*'. The main factors influencing agricultural production and therefore agricultural land quality are climate, site and soil. These three factors and the interactions between them form the basis of classifying agricultural land into one of five grades, as described in Table 1 below.

Table 1: Agricultural Land Classification Grades

Agricultural Land Classification Grades
Grade 1 – excellent quality agricultural land Land with no or very minor limitations to agricultural use. A very wide range of agricultural and horticultural crops can be grown and commonly include top fruit, soft fruit, salad crops and winter harvested vegetable. Yields are high and less variable than on land of lower quality.
Grade 2 – very good quality agricultural land Land with minor limitations which affect crop yield, cultivations or harvesting. A wide range of agricultural and horticultural crops can usually be grown but on some land in the grade there may be reduced flexibility due to difficulties with the production of the more demanding crops such as winter harvested vegetables and arable root crops. The level of yield is generally high but may be lower or more variable than Grade 1.
Subgrade 3a – good quality agricultural land Land capable of consistently producing moderate to high yields of a narrow range of arable crops, especially cereals, or moderate yields of a wide range of crops including cereals, grass, oilseed rape, potatoes, sugar beet and the less demanding horticultural crops.

Agricultural Land Classification Grades (continued)
Subgrade 3b – moderate quality agricultural land Land capable of producing moderate yields of a narrow range of crops, principally cereals and grass or lower yields of a wider range of crops or high yields of grass which can be grazed or harvested over most of the year.
Grade 4 – poor quality agricultural land Land with severe limitations which significantly restrict the range of crops and/or level of yields. It is mainly suited to grass with occasional arable crops (e.g. cereals and forage crops) the yields of which are variable. In moist climates, yields of grass may be moderate to high but there may be difficulties in utilisation. The grade also includes very droughty arable land.
Grade 5 – very poor quality agricultural land Land with very severe limitations which restrict use to permanent pasture or rough grazing, except for occasional pioneer forage crops.

Agricultural land of Grade 1, 2 and Subgrade 3a is considered to be the best and most versatile (BMV) agricultural land in England and Wales.

Two of the principal limitations to agriculture, considered by the ALC system, are soil wetness and soil droughtiness. Soil wetness limits the flexibility of agricultural land by reducing the number of days available for safe cultivations and harvesting. The greater the soil wetness limitation the fewer days available. Soil wetness is influenced by climate (i.e. rainfall v evapotranspiration) and soils (primarily the soil water / drainage regime and topsoil clay content). Soil droughtiness limits the capacity of agricultural land to economically support certain crops. The greater the soil droughtiness limitation the less crop available water there is during the growing season and the less economically viable certain, or in the worst cases all, crops become. Soil droughtiness is influenced by climate (e.g. rainfall v evapotranspiration) and soils (primarily soil structure, soil depth, soil stone content and soil texture).

An assessment of soil wetness and droughtiness can demonstrate the residual impact of solar PV sites on agricultural land quality.

3.1 'Disturbed' and 'Undisturbed' Agricultural Soils / Land

In areas of a solar PV site, including the compound, access tracks, bases for inverters/substations, the soil will be stripped during the construction phase, stored and then replaced at the time of decommissioning. In areas of cable trenching the soil will be

stripped, placed close to the trench and then reinstated once the cable is in place. In this report these areas are considered to be *'disturbed'*.

For this report areas in which soils are not stripped or reinstated and remain in situ are considered to be *'undisturbed'* land. These areas of 'undisturbed', soils may still be impacted during the various construction phases, via trafficking.

The ALC system recognises the classification of 'disturbed' land, which has different criteria for classifying land from 'undisturbed land'. Therefore the two are assessed differently:

- the agricultural quality of *'disturbed'* land is assessed with reference only to the soil textural, structural and porosity characteristics.
- the agricultural quality of '*undisturbed'* land is assessed with reference to soil colour (gleying[3]), textural, structural and porosity characteristics for determining the soil wetness limitation.
- the assessment of soil droughtiness for both 'disturbed' and 'undisturbed' land considers the soil texture, structure, organic matter and stone content.

3.2 Agricultural Land Classification Grade Scenarios

In the following sections several scenarios are outlined to indicate the potential residual impacts of solar PV sites on agricultural land quality. The scenarios concentrate on the residual impact of unremediated soil compaction on agricultural land, specifically relating to ALC grade according to soil wetness and soil droughtiness.

The assessment of ALC grade according to soil wetness (MAFF ALC Guidelines Section 3.4 and Appendix 3) considers climate, soil water regime and soil texture. Soil water regime is influenced by climate plus subsoil structure, consistency and porosity – each of which will be impinged by unremediated compaction.

The scenarios assume that unremediated (sub)soil compaction has resulted in a slowly permeable layer (SPL) at a shallower depth in the soil profile than was previously the case. The depth to a SPL is key to assessing soil water regime and ultimately ALC grade according to soil wetness. A SPL prevents the downwards movement of water in the soil profile and can lead to surface water perched at shallow depth for periods of the year, particularly autumn through to spring, and particularly problematic in wetter soil types or wetter areas

[3] A greyish, pale and ochreous colouring indicative of waterlogging.

of England and Wales. This can negatively impact the flexibility of agricultural land, potentially lowering quality and ALC grade.

A similar set of scenarios could be made of the potential residual impact of unremediated (sub) soil compaction on ALC grade according to soil droughtiness. The assessment of soil droughtiness considers climate, soil texture and, again, soil structure, consistency and porosity.

Several scenarios have been prepared to demonstrate the impact on soils using Field Capacity Days covering a range of hypothetical climates across England and Wales. Field Capacity Days (FCD) is a theoretical climatic model of the number of days in a typical year that accumulated precipitation exceeds accumulated evapotranspiration. It is based on historical climatic data in England and Wales, and wetter, cooler areas have higher FCD (e.g. >300 FCD in Welsh hills) than warmer, drier areas (e.g. 100 FCD in SE Cambridgeshire). It corresponds with the soil concept of Field Capacity, is the water content of a soil after gravitational drainage over approximately a day.

As is standard with the ALC system, the scenarios assume that soils have or could have an appropriate underdrainage system and the assumption is made that such a system will be in place at the end of the solar PV site decommissioning phase.

Several examples are presented to demonstrate the residual impact of an introduced SPL (caused by unremediated subsoil compaction) and the interaction with the climate variable Field Capacity Day (FCD) on BMV agricultural land. A summary of the scenarios is given below and detailed tables are in Appendix 5.

3.2.1 Scenario 1: Wetness Class I Medium-Textured Soils (Disturbed Land)

Several scenarios for 'disturbed' soils are presented in Appendix 5 (Table A) to demonstrate the residual impact of an introduced SPL (caused by unremediated subsoil compaction) on BMV agricultural land.

The following summary demonstrates the potential impact on land during the lifetime of a solar PV site. The pre-construction soil profile belongs to Wetness Class I[4] and has a medium-textured topsoil. During the construction phase the soil is stripped and stored in soil bunds.

[4] Wetness Class (WC) I = freely-draining soil. WC II = moderately freely-draining. WC III = imperfectly-draining. WC IV = poorly-draining. WC V = very poorly-draining. WC VI = permanently waterlogged.

- in an area with a FCD of 230 the impact of an introduced slowly permeable layer at a depth of between 25cm and 60cm would place the reinstated soil profile in Wetness Class IV and the agricultural land classification grade of Subgrade 3b. The agricultural land classification grade before commissioning would be Subgrade 3a, hence there is an impact at decommissioning on BMV land.
- in a drier part of England, with a FCD of 125, with an introduced SPL at a depth of between 35cm and 60cm, the reinstated profile is placed in Wetness Class III and the resultant ALC grade is Subgrade 3a. Prior to commissioning the ALC grade is given as Grade 1, hence there is an impact on the versatility of the BMV land at decommissioning.

3.2.2 Scenario 2: Wetness Class I Medium-Textured Soils ('Undisturbed' Land)

Several scenarios for 'undisturbed' soils are presented in Appendix 5 (Table B) to demonstrate the residual impact of an introduced SPL (caused by unremediated subsoil compaction) on BMV agricultural land. For 'undisturbed' soils reference is made to soil colour (gleying[5]), textural, structural and porosity characteristics for determining the soil wetness limitation.

The scenario is a pre-construction soil profile placed in Wetness Class I, which has a medium-textured topsoil:

- in an area with a FCD of 230, where there is an introduced slowly permeable layer at a depth of between the surface and a depth 80cm with gleying present below a depth of 40cm, the soil at decommissioning is placed in Wetness Class III and an ALC grade of Subgrade 3b. Prior to commissioning the ALC grade is given as Grade 3a, hence there is an impact at decommissioning on the BMV land.
- in an area with a FCD of 230, where an introduced slowly permeable layer is present at a depth of 25cm and gleying is present in the soil profile above 40cm the soil is placed in Wetness Class V and Grade 4. There is an impact at decommissioning on the BMV land.
- in a drier part of England, with an FCD of 125, where there is gleying present below a depth of 40cm and a slowly permeable layer starting between a depth of 35cm to 42cm the soil at decommissioning is placed in Wetness Class III and Subgrade 3a.

[5] A greyish, pale and ochreous colouring indicative of waterlogging.

Prior to commissioning the ALC grade is given as Grade 1, hence there is an impact on the versatility of the BMV land at decommissioning.

3.2.3 Scenario 3: Wetness Class II Light-Textured Soils (Disturbed Land)

Several scenarios for 'disturbed' soils are presented in Appendix 5 (Table C) to demonstrate the residual impact of an introduced SPL (caused by unremediated subsoil compaction) on BMV agricultural land. The pre-construction soil profile belongs to Wetness Class II[6] and has a light-textured topsoil. During the construction phase the soil is stripped and stored in soil bunds.

The following summary demonstrates the potential impact on land during the lifetime of a solar PV site:

- in an area with a FCD of 225 the impact of an introduced slowly permeable layer at a depth of between 25cm and 60cm would place the reinstated soil profile in Wetness Class IV and the agricultural land classification grade of Subgrade 3b. The agricultural land classification grade before commissioning would be Grade 2, hence there is an impact at decommissioning on BMV land.
- in a drier part of England, with a FCD of 125, with an introduced SPL at a depth of between 35cm and 60cm, the reinstated profile is placed in Wetness Class III and the resultant ALC grade is Grade 2. Prior to commissioning the ALC grade is given as Grade 1, hence there is an impact on the versatility of the BMV land at decommissioning.

3.2.4 Wetness Class II Light-Textured Soils ('Undisturbed' Land)

Several scenarios for 'undisturbed' soils are presented in Appendix 5 (Table D) to demonstrate the residual impact of an introduced SPL (caused by unremediated subsoil compaction) on BMV agricultural land. The pre-construction soil profile belongs to Wetness Class II and has a light-textured topsoil.

- in an area with a FCD of 225 the impact of an introduced slowly permeable layer at a depth of between 35cm and 61cm and gleying present above 40cm would place the profile in Wetness Class IV and the agricultural land classification grade of

[6] Wetness Class (WC) I = freely-draining soil. WC II = moderately freely-draining. WC III = imperfectly-draining. WC IV = poorly-draining. WC V = very poorly-draining. WC VI = permanently waterlogged.

Subgrade 3b. The agricultural land classification grade before commissioning would be Grade 2, hence there is an impact at decommissioning on BMV land.

- in a drier part of England, with a FCD of 125, with an introduced SPL at a depth of between 35cm and 61cm and gleying above 40cm, the profile is placed in Wetness Class III and the resultant ALC grade is Grade 2. Prior to commissioning the ALC grade is given as Grade 1, hence there is an impact on the versatility of the BMV land at decommissioning.
- in areas with a FCD of 170 or lower with a light-textured soil changes in the Wetness Class and resultant grade may have minimal impact on BMV land (Appendix 5 Table D). However the introduction of a slowly permeable layer may influence the available water holding capacity of the soil profile and soil droughtiness may have an impact on the BMV land.

3.2.5 Summary

To summarise on both disturbed and undisturbed land, the soil wetness assessment shows the impact of unremediated soil compaction leading to gleying in the soil and the introduction of a slowly permeable layer. The potential loss of BMV agricultural land or its versatility increases in wetter parts of England and Wales.

In slightly drier parts of England and Wales there is loss of BMV agricultural land depending on the starting depth of the slowly permeable layer. Loss of versatility of BMV agricultural land, for the soil textures considered, occurs in slightly drier parts depending on the interaction of the Wetness Class and the FCD of the location.

3.3 Soil Compaction and Soil Droughtiness

Section 3.4 and Appendix 4 of the MAFF ALC Guidelines (1988) outline the methodology for assessing the soil droughtiness. Soil droughtiness indicates the degree to which a shortage of soil water may influence the range of crops grown and the yields achieved. Droughtiness is more likely to be a limitation to crop growth in areas of relatively low rainfall or high evapotranspiration. The interaction of the climate, soil texture, soil stoniness, subsoil structure, subsoil porosity and subsoil consistency influences the degree of the severity.

On solar PV sites both disturbed and undisturbed land at decommissioning may be affected by the introduction of unremediated soil compaction. This could reduce the crop available water of the soil profile, changing the ALC grade in the soil droughtiness assessment and may result in downgrading and /or loss of BMV.

The change in the grade may arise from a change in the soil profile characteristics, particularly soil consistence (the resistance to crushing) leading to changes in the available water holding capacity in the subsoil. The following scenario shows the impact of a change in the available water capacity of a subsoil on BMV land:

- Location – south east England
- Climatic moisture deficit for wheat is 122mm and potatoes 118mm
- ***Prior to commissioning***: the profile subsoil has a good structural condition with the resultant crop adjusted water capacity for wheat of 110mm and for potatoes of 89mm.

  The moisture balance limits place the profile in Subgrade 3a
- ***At decommissioning***: the profile subsoil has a moderate structural condition with the resultant crop adjusted water capacity for wheat of 106mm and for potatoes of 85mm.

  The moisture balance limits place the profile in Subgrade 3b.

In more severe cases unremediated soil compaction may prevent root penetration. Occurring at shallow depth this may have a significant impact on crop available water which may result in downgrading by more than one ALC grade. The depth of root penetration can only be assessed by the examination of soil pits.

3.4 Soil Mixing

Soil mixing may occur in the construction and decommissioning phases and is identified in Section 3.3 of the ALC Guidelines (MAFF,1988) as a potential limitation to grade. A study of the effects of golf course development on high quality agricultural land (MAFF,1995) considered the impact of soil mixing on the reversibility of high quality agricultural land. Where mixing of very different soils e.g. sands with clays occurred subsequent agricultural management was potentially difficult. The severity of the impact will depend on the amount of mixing- the ratio of different soil textures and other soil properties such as soil structure, stone content and organic matter content. It is difficult to assess the impact on BMV agricultural land from soil mixing but where it causes significant management problems, post-decommissioning, an independent assessment would be required – both to quantify and to remediate.

3.5 Reversibility or otherwise of the impacts on BMV agricultural land

One of the key impacts on BMV agricultural land is soil compaction, which can vary considerably from very minimal and short term to severe, which possibly cannot be rectified. Compaction in the subsoil below about 45cm is unlikely to be practicable and economic to alleviate (Batey, 2009) and is unlikely to respond quickly to natural recovery through the freeze-thaw cycle. Where compaction is present at depth it is a long-term limitation and it is taken into account in the ALC Guidelines (MAFF, 1988) through reduced permeability in the wetness assessment and crop available water in soil droughtiness assessment. There will be compaction at the time of construction, which may remain for the lifespan of the development. Further compaction may result at the decommissioning phase.

The timescale for reversibility is undefined but is taken in this report as the point at which decommissioning is completed. The time taken for a soil with compaction to recover depends on the severity of the compaction and the soil type. Business Wales (2018) and Froehlich et al (1985) reported that natural recovery of a compacted soil is complex and a slow process. Batey (2009) refers to 30 years for a compacted soil to recover, where 'industrial' compaction extends to depths of 1m or more (Spoor, 2006). Hakansson (1988) reported that compaction may be very persistent in the subsoil and permanent. Nawaz et al (2012) presented a review of research and concluded that soil compaction is rapid and easy to create with agricultural machinery but it can be years before the soil is recovered. Keller at al (2017) noted that knowledge regarding soil compaction rates is 'sketchy' with experimental evidence of recovery periods from a few months to years and decades. Differences in laboratory and field experiments highlight the 'partial and incomplete' knowledge of the key processes involved in soil structure recovery.

Keller et al (2021) undertook research at the Swiss Soil Observatory to quantify and monitor short-term recovery after prescribed compaction. After 2 years it was noted that different soil physical properties follow different recovery paths and rate. Bulk density and air permeability had not fully recovered to pre-compaction values in the topsoil and subsoil. Post compaction recovery rates decreased with soil depth and differed between soil properties.

A study of soil compaction on golf courses (MAFF, 1995) reported that the inappropriate handling of soils resulted in severe compaction and a deterioration of soil structure. In the period 1988 to 1993 construction work, such as soil stripping and trafficking, was undertaken on a number of golf courses during the winter months. A finding of the report was that if soil stripping had been carried out in a more controlled way parts of golf courses might have

been practically reversible to an agricultural land quality closer to the pre-construction quality.

A study undertaken by Defra (2016) considered compaction in grassland on 300 grassland fields. The study considered how grassland management may be used to influence soil compaction and how management can be targeted to alleviate or avoid compaction. The careful management of machinery use in terms of when and how many times soils are trafficked was a key influence on the level of soil compaction.

Current techniques for alleviating compaction above depths of 45cm, particularly in drier parts of England and Wales, indicate that some reversibility of the impact on BMV agricultural land is possible. However not all soils respond and silty soils, where there is structural instability, may be problematic.

Where deep compaction occurs in soil the reversibility of the impacts on BMV agricultural land are given in scenarios (sections 3.2.1 to 3.2.4 and Appendix 5). The impact of compaction on disturbed soils and undisturbed soils are assessed separately. In the case of disturbed soils there may not be any compaction if the soils associated with cable trenching are replaced in an unconsolidated condition. There are many unpredictable factors, such as soil strength and prevailing moisture content, that will affect the level of compaction and the potential to successfully alleviate damage.

In the case of compacted soils and the pre-construction Wetness Class I soil, reversibility involves the removal of the slowly permeable layer within 80 cm at decommissioning. The ALC Guidelines (MAFF,1988) consider that '*where significant compaction occurs below 35cm… it may be difficult or impossible to ameliorate practically or economically. Such compaction is therefore a long-term limitation which is taken into account through reduced permeability and water capacity in the wetness and droughtiness assessments*'.

Batey (2009) reports that techniques for loosening compact soils operating to depths of about 45cm are established. In the case of a soil profile in Wetness Class II it may be that the impact on BMV agricultural land is reversible and some loss of versatility is reversed. For example, in the drier parts of England with a FCD of 125 where there is compaction close to a depth of about 45cm and gleying present below a depth of 40cm, then the impact of compaction on BMV agricultural land is normally reversible, with the Wetness Class moving from Wetness Class III to Wetness Class II.

Any soil mixing may impact on BMV agricultural land but each site will have individual characteristics and it is difficult to prescribe for a potential impact. Small amounts of soil mixing should be reversible as the subsoil and topsoil are mixed by cultivation and soil biota but where significant soil mixing does occur the reversibility of the impact on BMV agricultural land becomes increasingly challenging.

4 POTENTIAL IMPACTS (POSITIVE AND NEGATIVE) ON SOILS DURING THE OPERATIONAL PHASE

4.1 Introduction

During the operational phase of the solar PV site there are minimal activities on site and the site is usually unmanned. Routine maintenance at the site may include grass cutting, if grazing does not keep the grass at the optimum height, landscape management (e.g. hedge trimming) and an annual PV panel wash. The electrical systems may be monitored monthly and a grazier to manage stock grazing may access the site. Access is typically by 4x4 vehicles and it is unlikely that any heavy machinery will be required.

Grazing of grassland by sheep required careful management. Excessive stocking rates and / or grazing on soils susceptible to damage during wet weather, may negatively impact the soil during the operation phase and may pose environmental issues such as increased surface water runoff.

4.2 Claimed benefits of topsoil carbon capture and soil structural improvements

Much guidance (BRE, 2013 and 2014a) and many planning applications promote the benefits to biodiversity of solar PV sites.

Agricultural land use change, often from arable use, on BMV agricultural land to low-maintenance grassland, has been cited by developers in planning applications as a benefit arising from solar PV sites. Soil carbon, mainly derived from carbon fixed by plants, is stored in soils in the form of soil organic matter (SOM). SOM is the cornerstone of soil health; it is beneficial to soil structure, the resistance of the soil to erosion, plant / crop available water, plant / crop available nutrients, earthworm numbers, soil microbiology and biodiversity etc. Furthermore, as a carbon store it is of particular importance today and in the future.

Reports of changes in soil carbon resulting from land reversion are reported by Conant et al (2001). More recently Connant et al (2017) have studied data since 2001 and confirm their earlier conclusions that improved grazing management, fertilization, sowing legumes and improved grass species and conversion from cultivation all tend to lead to increased soil carbon (C).

Defra (2009) reported that the quantity of C that can be stored in any soil is finite. Following a change in management practice levels C can increase (or decrease) towards an equilibrium value at about 100 years depending on the soil type, land use and climate. The relatively

'high' annual rate of C storage reported in the early years following a land use change from arable use to a grassland use does not continue and the rate of accumulation will decline until a new equilibrium is reached. Where the land use change is from long term grasslands it is expected that the initial properties at commissioning of the solar PV site would be different from short term grassland and arable land.

Maintaining an increased SOM level, due to a change in management practice, will be dependent on continuing that practice indefinitely. Only if land is taken permanently out of arable cultivation or rotation will the benefits of C storage be realised over the long-term. Soil organic matter is more rapidly lost than it is accumulated (Freibauer et al, 2004).

A study by Gosling et al (2017) considered the potential for the conversion of arable cropland to grassland to sequester carbon in the short to medium term. The study reported no difference in soil organic carbon stocks in the top 30cm of the soil profile in grassland up to 17 years old and arable cropland at sites across the UK.

The conversion of tillage to grassland resulted in an increased carbon storage in the range 1.1 to 7.0 CO_2e/ha/year (Dawson and Smith, 2006). Conversion of grassland to tillage cropping was estimated to result in carbon losses in the range 2.2 to 6.0 CO_2e/ha/year. It was also reported that converting areas of farmland to grass buffer strips and hedges/shelter belts would enhance soil organic matter and increase C storage on a smaller scale. The baseline soil reference values prior to commissioning are key to understanding any change in SOM over the lifetime of the solar PV site. The land use and factors, such as the changes in management practices e.g. reduced tillage operations, at each site prior to commissioning impact on the baseline soil reference values and potential level of change in SOM.

The relationship between increased SOM and improved soil structure is documented (Cranfield, 2001) and recognised in land management practices with minimum tillage or no tillage operations (Game and Wildlife Conservation Trust, 2020). It is also recognised that reverting arable agricultural land to low-maintenance grassland will improve soil structure. The term soil structure refers to the shape, size, orientation, degree of development, porosity and consistency of aggregates of soil particles. Structure influences the movement of air, water, carbon, nutrients, roots and microorganisms within soil. An improved soil structure is beneficial to many of the key ecosystem services performed by soils, including regulation of air and water, carbon capture and support of plants.

Choi et al (2020) undertook a study in Colorado USA on the effects of revegetation on soil physical and chemical properties in solar PV infrastructure over a 7- year period. The study

found that soils at the solar PV site contained significantly less carbon than the reference soil. This was likely to be caused by the removal of topsoil during the array's construction. The ability of the soil on the site to sequester carbon was diminished relative to reference soils. The study suggested mitigation in the adoption of minimum topsoil disturbance during construction.

Key points from studies on land use changes and soil carbon include:

- The initial increases in the early years do not continue
- To maintain an increase in the level of soil carbon the land has to be taken permanently out of arable cultivation or rotation
- Soil organic matter is more rapidly lost than it is accumulated.

There is limited evidence specifically relating to solar PV sites to confirm the benefits to soil health. Baseline site specific soil reference values are required with long-term monitoring to provide evidence of the changes and legacy in the soil health at a solar PV site over a typical lifetime of 40 years.

Factors such as the disturbance of the soil at the construction phase may impinge the development of benefits through the operation phase. Even in the most successful cases (of soil carbon capture, health and structure improvement), improvements are likely to be only temporary and decrease with disruption at decommissioning and again at the return to arable cropping.

The physical presence of solar PV arrays on land is known to cause seasonal and diurnal variations in air and soil microclimate (Armstrong et al, 2016). The work by Alona Armstrong and her team at Lancaster University, particularly the work of Carvalho et al (2021), is looking at the effect of solar PV sites on soil specific factors, including soil organic carbon, nutrients and pH, bulk density, above ground biomass, soil microbial community etc. The work is in its early stages but managed to survey 35 solar PV sites in England and Wales in 2021 and will survey more sites in 2022. This and further such work could be very instructive.

In summary, further evidence is required to substantiate the benefits of SOM at solar PV sites and the claims cited by developers in planning applications.

4.3 The influence of shading and microclimates beneath panels on soil microbial activity

While the increased levels of SOM are recognised in grassland systems, the full impact of the physical presence of solar PV arrays on grassland management is open for discussion. Armstrong et al (2016) investigated the effects of solar PV arrays on microclimate and the consequences for carbon (C) cycling at Westmill Solar Park. The research found that PV arrays can cause both seasonal and diurnal variation in the ground-level microclimate such that there was an effect on terrestrial C cycling. One of the conclusions of the project is that the effects of solar PV sites on plant–soil processes, which underpin key ecosystem services, is poorly understood.

The microclimatic variability within a solar PV site arises from a lower temperature under the PV arrays. The above ground plant biomass was four times higher in the gap between arrays and the control areas compared to the biomass under the PV arrays. The soil temperature is cooler under the PV arrays and between the PV arrays during the winter due to the interception of shortwave radiation by the solar PV arrays.

The shadow cast by the PV arrays varied from under 2 m in the month of June to just under 11 m in the month of December. The cooling is likely to be significant in terms of ecosystem function with the temperature differences affecting key plant-soil processes from productivity to decomposition (Marrou et al 2013). Thomas et al (2020) expected rising soil temperatures on site would increase soil organic carbon losses due to the increased rates of microbial decomposition.

Recent work in the Netherlands has considered the design of the site layout and the impact on soil (van Aken et al 2021). A comparison of the amount of ground irradiance in terms of intensity and distribution between two south-facing solar park configurations and east-west orientated panels was made. Two variants were made- one with standard solar panels and another with semi-transparent solar panels and bifacial panels. A 77% coverage with semi-transparent and bifacial panels 'performed better on soil quality' with a more even distribution of light on the soil than standard panels with a 53% coverage. The study recommended the establishment of criteria for ground radiation under and between panels.

4.4 The influence of solar developments on soil loss and erosion

Soil loss can occur during the construction phase as soil is stripped for the construction of a compound, bases for inverters and substation, and access tracks. Many solar PV site layouts

do not plan space for soil storage bunds and propose to spread the soil in thin layers alongside the access track. This leaves the stripped soil barely visible in the landscape and difficult to reclaim at the restoration phase. This approach is likely to contribute to soil loss, as the soil will not be recovered to its original volume at the decommissioning phase.

Across a solar PV site disturbance can cause the loss of the surface vegetation (see Appendices 3 and 4) and this will leave a site far more vulnerable to soil loss from erosion.

Runoff from solar panels has an influence on soil erosion. Water is known to run along the edge of the panels then fall to the ground at localised points and form rivulets. This has the potential to cause soil erosion, the risk of which is strongly influenced by slope and soil type. Choi (2020) reported erosion and one of the case studies in WP2a (Estuary Farm[7]) considered the possibility of runoff from solar panels causing compaction of soils at the base of the panels and resulting in rivulets forming along the edge of the rows of panels. While there may not be a significant increase in runoff, small channels will have formed with potential of soil loss. This problem is likely to be more severe in erodible soils such as sandy soils on slopes before a vegetation cover establishes. However, the steepness of the slope would be an even stronger influence. The risks are repeated at the construction and decommissioning phases.

4.5 A summary of claimed benefits to soil from previous cases (WP 2a case studies)

The case studies referred to in WP 2a have been reviewed for any claimed benefits to soil within the supporting documentation.

- **Tyddyn Cae Solar Farm Gwynedd**[8] – there is reference to a reduction in nutrient input to the land as a result of changing from an arable use to grassland. The statement is made that 'soil health is essential for long term sustainability of farming, and solar farms could play an important role by resting soils through the life of the solar farm, allowing soil nutrients to restore naturally, without the need for regular use of fertilizers.' and reference is made to BRE (2014a).

[7] https://www.west-norfolk.gov.uk/planning_and_development Ref: 21/01432/FM

[8] https://amg.gwynedd.llyw.cymru/planning/index.html?fa=getApplication&id=24205 Ref: C14/0885/33/LL

- **New Works Solar Farm Telford**[9] – the site falls outside BMV agricultural land. There is no reference to claimed benefits to soil. Reference is made to the Solar Energy UK's publication 'The Natural Capital Value of Solar'.
- **Estuary Solar Farm, King's Lynn**[10] – there is no reference to claimed benefits to soil. The proposal is to use an 'under-utilised area of agricultural land' and enhance the 'once arable habitat' with wildflowers and species diverse grassland.

The case studies do not give any site-specific detail on benefits to soil in the supporting documents for the planning application.

[9] https://secure.telford.gov.uk/planning/pa-applicationsummary.aspx?applicationnumber=TWC/2021/0737 Ref: TWC/2021/0737

[10] https://www.west-norfolk.gov.uk/planning_and_development Ref: 21/01432/FM

5 ARE SOLAR PV SITES REVERSIBLE TO AGRICULTURE WITHOUT RESIDUAL (NEGATIVE) IMPACT?

5.1 Introduction

A brief review and summary of the hypothesis: '*that solar PV sites are physically reversible to agriculture without residual (negative impact) in the BMV and Non-BMV context*' is presented. The evidence base to support this hypothesis and the main issues influencing reversion to agriculture are identified.

5.2 Evidence Base

The key residual impact on the land is soil compaction. Defra (2016) reported that careful management of machinery use in terms of when and how many times soils are trafficked was a key influence on the level of soil compaction on grassland.

Current techniques on alleviating soil compaction are effective in the topsoil and upper subsoil, generally above a depth of 45cm (Batey, 2009). The depth of the uppermost compacted layer (e.g. after remediation) may be the determining factor in the realisation of potential agricultural use. Keller et al (2021) provide evidence that the recovery of soil from compaction was longer than 2 years. Compaction may be very persistent in the subsoil and possibly permanent (Hakansson et al 1988). Where there is 'industrial' compaction the depth of compaction can extend to depths of 1 m (Spoor, 2006) and may persist for up to 30 years (Batey, 2009). A review by Nawaz et al. (2021) refers to time scales of 5 to 18 years for soils to recover from compaction with the aid of agricultural machinery and for soil to recover from compaction naturally (without aid) 100 to 150 years.

At the point of decommissioning there is likely to be a residual impact of soil compaction across solar PV sites. The impact may affect the agricultural use of the land and decisions about cropping and yields.

Soil mixing has been reported by Choi (2020) where there was a greater fraction of coarse particles in the study solar PV site soil than the reference soil. It was considered that the difference arose during the construction phase, when the topsoil was disturbed and fine soil particles were lost by water erosion. Soil mixing has potential to occur at other stages in the life of a solar PV site, such as pile extraction.

5.3 The main issues influencing reversion to agriculture

At decommissioning all materials are expected to be removed including the removal of piles from the soil. Most standard steel products corrode, particularly in the upper part of the pile and this may adversely affect the ability to extract the piles after 40 years. (Non-corrosive materials could be used but have cost implications). It may be that piles fracture and are difficult to extract without additional digging. An engineering solution, where extraction is adversely impacted, would be to partially cut down the piles and provide a capping layer of soil (per comm. P Woodfield, Technik GS). Any residual piles are likely to have a negative impact on whether the land is physically reversible to agriculture unless buried sufficiently deep to enable cultivations and drainage. Where residual piles could not be buried to a depth to allow cultivations the grading of the land would take into account the severity of the limitation. Land with severe or very severe limitations, which restrict the range of crops, is placed into either Grade 4 or Grade 5 in the MAFF Agricultural Land Classification system. To bury the piles to a sufficient depth would mean excavating to a depth of at least 1.0-1.2 metres. This would result in significant soil disturbance if many of the piles were affected in this way.

Where galvanised beams are used zinc is present in the galvanised coating. There are two methods of galvanising used- 'continuous galvanising' and 'batch hot dip galvanising' (per. comm. A Whalley, Milestone Communications). Continuous galvanising (DIN EN 10327) gives a thinner coating, so the expected life is lower. If the beams are batch hot dip galvanised then standard ISO14713-1 applies, which includes reference to exposure to soil. Corrosion in soil is dependent on the soil's mineral content, the nature of the minerals and organic components and the water and oxygen contents. The impact of any interaction between the piles and the soils and potential loss of zinc coating over 40 years and whether there is any residual impact may need to be considered (per. comm J Williams, ADAS). Guidance from Defra (2018) on the use of sewage sludge on land states that the maximum quantity of zinc that can be applied per ha is 150kg over 10 years. Potentially any loss of zinc from piles could be well within this limit, but there is no supporting evidence. There is also evidence that high zinc levels in soils affects the soil biological activity (Moffett et al, 2003).

Handling soil in suitable conditions has an influence on the reversion of land to agriculture. Different soil textural classes have more resilience to structural damage and are more responsive to remediation during soil handling. Light textured soils e.g. sand, loamy sand, sandy loam and sandy silt loam have a higher resilience to structural damage than medium texture soils e.g. soil with 18-27% clay content. Silt loam soils and heavy soils with >27% clay

content have a low resilience to damage. Soil should only be handled or trafficked when as dry and as friable as is practicable. If handled or trafficked in adverse conditions damage to the soil structure can easily occur.

The period available for soil handling and trafficking on a solar PV site can influence the impact on the soil, the resultant structural damage and reversion to agriculture. The Institute of Quarrying (2021) has prepared a map of England and Wales showing climatic zones when vegetated mineral soils may be in a sufficiently dry condition according to their geographic location, depth of soil and clay content. When the clay content is between 10% and 27% in the topsoil in Wales, the South West and North of England the indicative on-average period when soils may be in a sufficiently dry condition for handling is generally late May to early October. For similar soils in central parts of England it is generally late April/early May to early November, while in the East of England it is generally late April to early December. The location of the proposed solar PV site and susceptibility of a soil type to structural damage should be considered at the design stage to ensure timeliness of soil handling and trafficking. A soil in West Wales with a medium clay loam texture and clay content of 24% will have a shorter window for soil handling and trafficking than the same soil in East Anglia. The impact of climate and climatic zones should be built into the design statement at the pre-planning stage of a site.

A research study into end of life decision making for solar farms (Windemer,2021) reported that there may be changes in ownership of the solar PV site with a change in the priorities for the site. The study considered finance for decommissioning, reporting that bonds are not always used in the solar sector as it is 'felt that decommissioning will not present a challenge'. The study found that some developers considered that decommissioning may be self- funding through the resale value of equipment and materials from the site. A sample decommissioning plan (Solar Energy UK, 2022) refers to the provision of a decommissioning fund either through a surety bond, an irrevocable standby letter of credit or other financial security.

Developers may consider that the scrap value of the panels etc on site will cover the costs of decommissioning. There are few contingency plans in place and should operators encounter financial instability and the economics of solar PV change during the project life and trigger early decommissioning then this may influence the reversion of the site to agriculture and other changes of land use may be sought.

Finances available for decommissioning are part of the responsibility of the operator or landowner or both and can influence the reversion to agriculture. It is the responsibility of the planning authority to ensure that the developer or landowner has secure finances or a bond in place to fund decommissioning.

5.4 Summary

There is evidence that soil compaction from machinery can have a residual impact on soil and land. Soil mixing may occur during construction and in the voids left after piles are extracted. Soil compaction and mixing may result in issues for land management. Removal of physical infrastructure on site and re-instatement of soil/land is necessary if the land is to be capable of reversion to a BMV agricultural land quality as well as a non BMV agricultural land quality.

The finance available for the required decommissioning and the timings of these operations may be an influencing factor on the reversion to agriculture. There may be financial constraints, time penalties and contractual performance issues that affect the decommissioning programme and the quality of remediation works.

6 THE PARALLELS BETWEEN MINERAL SITE RESTORATION AND SOLAR PV SITE RESTORATION

There are a few parallels between mineral site restoration and solar PV site restoration. In both situations soil will have been subject to stripping, some form of storage and then spreading over a subsoil. Subsoil compaction is likely to be found in both situations.

There are significant differences in the approach to restoration undertaken.

- Mineral site restoration is detailed as part of the planning application stage, supported by a soil resource management plan and restoration is subject to a statutory aftercare period of 5 years. There is published guidance for solar PV sites (BRE, 2013) recommending that a soil resource management plan be prepared as part of the planning application. Where soil resource plans have been prepared they have usually been undertaken as a condition of planning approval.
- While mineral sites require planned soil storage in the form of bunds many solar PV site layouts do not typically accommodate soil storage in bunds within the site and soil may be spread thinly alongside access tracks on undisturbed land.
- Solar PV site restoration involves the pull out of piles with soil disturbance at the decommissioning phase.
- Only part of a solar PV site generally requires restoration with soil spreading. Most of the area is not disturbed by soil stripping but is subject to trafficking and therefore may be compacted. Mineral site restoration good working practices involve spreading the soil in such a way that trafficking is minimised but all the soil is disturbed leading to a greater disturbance of soil structure and soil biota.

In summary, there are significant differences between mineral site restoration and solar PV site restoration. The main parallel is the need for a soil management plan to protect the soil resource.

7 THE PARALLELS BETWEEN GOLF COURSES OR SIMILAR SOFT USES AND SOLAR PV SITE RESTORATION

There are very limited documented experiences of the reversibility of golf courses to agriculture.

Parallels between golf courses and solar PV sites can be found where there is site levelling and movement of soil. Golf course restoration to agriculture may involve the importation of fill and some land levelling. Fill may also have been imported at the golf course construction stage. Landscaping forms part of both golf course development and solar PV site.

The presence of physical infrastructure on a solar PV site where there may be a high density of piles (e.g. 492 piles per ha) and extensive lengths of trenching for cables are significant differences. The extent of constructed infrastructure on solar PV sites may be greater than on a golf course. The impact of compaction from trafficking would be expected to be greater on a solar PV site than a golf course development, although surface sealing on golf courses can be an issue due to footfall.

A study (MAFF,1995) reviewed the effect of golf course development on Grades 1, 2 and 3a land. The potential adverse effects that impact on high quality agricultural land are from earth moving during construction, soil mixing, sterilisation of land and construction of clubhouses and car parks. The impact of a golf course on land was defined as 'high' (more than 50% of the land irreversibly lost) to 'low' (10 to 25% of the land irreversibly lost). In the study 'irreversible' was defined as the *'ability to restore a site to a similar agricultural land quality which existed prior to development. It is not just the ability to restore land back to agricultural use'*.

The greatest irreversible loss of high quality agricultural land on golf courses resulted from earth shaping and sterilisation of land. Golf courses with the lowest impact used existing landform with little disturbance to the agricultural land. Soil mixing and compaction tended to be localised and the impact on the ALC grade of the land was variable. The study found that golf course constructions on over 30% of the courses took place in the winter period when conditions for soil handling were not suitable. The impact on high quality agricultural land and the reversibility to a similar grade was influenced mainly by the disturbance of the soil through earth moving.

Both golf courses and solar PV sites are presented as being reversible to an agricultural use.

The parallels for restoration between golf courses and solar PV sites include the disturbance of soil, soil mixing, trafficking of the land and unsuitable conditions for soil handling and trafficking during the construction, operation and decommissioning phases.

8 CAN SOIL HANDLING CONDITIONS, AS PART OF THE PLANNING PROCESS, MITIGATE OR REMOVE THREATS TO SOILS AND LAND

8.1 Soil Handling Conditions

Soil is moved through stripping, storage and replacement operations at the construction and de-commissioning phases of a solar PV site. Soil handling will be part of the construction of the site compound, access roads/track, bases for inverters and substations and cabling operations.

A soil resource assessment, undertaken as part of the pre-planning stage, gives a baseline of existing soil conditions on site. The assessment will identify different soil types and soil handling units, which will be required to be stripped, stored and replaced in discrete areas. Planning guidance on large scale ground mounted solar PV sites (BRE, 2013) recommends inclusion of a methodology for stripping, storage and replacement of soil within the developer's planning application. The Institute of Quarrying guidance on soil handling (Institute of Quarrying, 2021), applicable to the civil engineering and the wider construction sectors, refers to the need for a soil resource and management plan (SRMP) at design stage through to site closure. Defra's Code of Practice for the Sustainable Use of Soils on Construction Sites (2009) recommends the inclusion of a soil resource plan as part of pre-construction planning.

From the evidence ADAS has seen, it appears that the preparation of a soil resource and management plan (SRMP) for solar PV sites has usually been a condition of the planning permission granted by the planning authority – i.e. as a condition of permission rather than being prepared to support the planning application. The responsibility for the standard and quality of the SRMP lies with the planning authority.

The SRMP considers the management of soil at the construction phase and is a separate document to a decommissioning plan, which is generally conceived at a much later stage of the project life. From the perspective of protecting the soil resource the two documents should be closely intertwined.

While the preparation of a SRMP may meet a condition of the planning authority, on its own it cannot mitigate or remove the risks of harmful impacts on soil and land or be a guarantee for a successful outcome. The key to mitigation is how the SRMP is implemented, the time of year when construction work is undertaken and the day-to-day management on site during soil handling and trafficking. ADAS experience on infrastructure projects has shown

that the on-site presence of a soil scientist can ensure that soils are stripped at the appropriate depth and in suitable conditions for soil handling. A recording of soil stripping movements and storage locations should be made.

The lifespan of a solar PV site is generally around 40 years. To safeguard the soil resources for this number of years any soil stripped is best placed in planned storage bunds within the site boundary and a record of soil type and volume in each bund made. The physical and chemical conditions of the soil are likely to have changed from the pre-construction (pre-storage) baseline. Storage can cause a reduction in soil porosity and structure. The preparation of a remediation plan with an aftercare programme as a condition of planning permission will give details on soil handling, but the implementation is key to the outcomes.

8.2 Restoration of BMV agricultural land

A research project undertaken in the 1990s considered the quality of agricultural land at the post restoration stage for a number of mineral sites (Defra, 2000). The study included 34 sites with best and most versatile agricultural land quality and of these about half had maintained their pre-working grade at the start of the 5-year aftercare period and the majority had maintained or improved the grade at the end of the 5-year aftercare period. On these sites the soil was worked in phases over a much shorter period than a solar PV site lifespan and therefore was not in long-term storage.

There are many factors that can influence the outcome of restoration of Best and Most Versatile (BMV) agricultural land and these may include:

- The inherent soil properties and variability across the site
- The amount and duration of climatic wetness
- The daily weather conditions and the soil moisture assessment prior to and during soil handling with appropriate soil handling decision making
- Soil resource and management planning at an early stage in the planning process
- Trafficking the land when soils are in suitable conditions
- Recording details (soil type, volume) of stored soils
- Using appropriate machinery in suitable conditions.

Commercial pressures can influence a restoration programme, resulting in work taking place in unsuitable conditions, resulting in damage to the soil and potentially loss of BMV agricultural land.

The condition of the soil after removal from stockpiles will be a key factor in the realistic restoration of sites with BMV agricultural land. A programme of aftercare with finances provided to cover associated costs is essential if a there is to be a realistic restoration to BMV agricultural land.

At present the decommissioning of a solar PV site covers the removal of all physical infrastructure. Some developers refer to returning the site to its pre-development condition but give limited details. A detailed decommissioning plan is not required by planning conditions until near the end of the life of the site. The detail of a soil resource and management plan should inform the decommissioning plan.

Many solar PV sites change management over the period of operation and the agreements and responsibility for decommissioning at the granting of planning permission should be taken forward to the site closure.

It is important to note that soil is naturally fragile and restored soils remain particularly vulnerable for a variable period until the new soil structure has stabilised. This means that, even if all the correct plans and procedures are put in place and followed with best practice by all contractors during all phases, restoration of disturbed soil may still fail. This may occur when high rainfall causes prolonged waterlogging before the new soil structure has stabilised and causes the soils to slump.

8.3 BMV v non-BMV agricultural land

It is important to note, despite the risks of the construction, operation and decommissioning phases to BMV agricultural land, that in many instances the soils on BMV agricultural land may potentially be easier to restore after decommissioning than non-BMV. However much depends on the site location and interactions between climate and soil.

Non-BMV agricultural land, i.e. Subgrade 3b, Grade 4 and Grade 5, is described as moderate, poor and very poor quality land respectively. It has physical or chemical limitations ranging from moderate to very severe. On any land with heavier soil types in wetter, cooler climates the soil is likely to be more susceptible to damage during the construction, operation and decommissioning phases. There will be a shorter safe window for construction, decommissioning, aftercare and even sheep grazing through the operational phase. Where droughtiness is the main limitation the characteristics of a sandy soil profile with a moderately stony subsoil may be altered during soil handling and affect the water holding capacity of the soil profile at decommissioning, leading to a change in the ALC grade.

The management history of non-BMV agricultural land will influence the baseline soil reference values and the potential carbon capture benefit of solar PV sites. Land in Subgrade 3b may be used for cereals or grass, while land in Grade 4 may be used for grass with occasional arable crops. Land in Grade 5 is typically limited to permanent pasture or rough grazing.

There may also be greater environmental risks during construction, operation and decommissioning on non-BMV agricultural land. Soils may be at field capacity or have a clayey or silty soil texture with a landform resulting in surface water runoff. In such instances there may be a greater risk of soil erosion and pollution of water courses.

Key to managing the risks at any site is an adequate soil resource and management plan tailored to the individual site which is adhered to by contractors and which flows into an appropriate, and appropriately funded, decommissioning plan, including aftercare as required.

9 TYPICAL PLANNING CONDITIONS FOR RESTORATION OF AGRICULTURAL LAND

Planning conditions may be put in place by the planning authority to address matters of soil handling, storage, replacement and aftercare. An outline soil resource and management plan should be prepared taking into account an overview of the typical planning conditions, with attention to the times of soil handling. A detailed plan should be prepared as required, taking into account typical planning conditions. The potential planning conditions should be considered at the planning stage of the solar PV site and the limitations imposed on soil handling by soil and climate interactions. Welsh Government (2014) give an example of conditions applicable to solar PV development. These conditions are reproduced below and can be linked to the three phases in the life of a solar PV site.

9.1 Whole Lifetime site Condition

General Handling of Soils

All soils shall only be stripped, handled, stored and replaced in accordance with document *(insert ref.)* dated *(insert date)* except as modified by this schedule of conditions or unless otherwise agreed in writing with the Local Planning Authority. *Reason: To prevent loss or damage of soil, or mixing of topsoil with subsoil, or subsoil with aggregate or mixing of dissimilar soil types.*
Topsoil shall be stripped to a depth of *(insert ref. / mm)*, subsoil shall be stripped to a depth of not less than *(insert ref. / mm)* and they should be stored separately in mounds within the site. *Reason: To prevent loss of soil, and ensure the direct replacement of soil*
All topsoil and subsoil shall be permanently retained on site and used in restoration. *Reason: To prevent loss of soil.*
In each calendar month, the Local Planning Authority shall be notified in writing at least 7 days before each of the following stages: (a) Before each phase of soil stripping is due to commence; (b) When soil subsoil has been prepared ready for topsoil replacement to allow inspection of the area before further restoration of this part is carried out; and (c) On completion of topsoil replacement *Reason: To ensure that the Local Planning Authority is given opportunity to check that soil operations do not occur under unsuitable conditions and to provide sufficient notice for site inspection.*

Soil Stripping

In each calendar year, soil stripping shall not commence on any phase until any standing crop or vegetation has been cut and removed. *Reason: To avoid incorporation of concentrations of decaying vegetation in soil.*
Topsoil and subsoil shall only be stripped when they are in a dry and friable condition. The developer shall give 48 hours notice to the Planning Authority of the intention to carry out any soil movement operation and no movement of soils shall occur: (a) During the months May to October (inclusive), unless otherwise agreed in writing with the Local Planning Authority; and, (b) Topsoil and subsoil handling for the restoration of land to agriculture, shall cease during rain, applying the following criteria: (i) If there is light rain or drizzle, handling can proceed for up to four hours unless the soils are already in too moist a state (see tables below); (ii) If there is light rain, handling will cease if the rain has not stopped in 15 minutes; (iii) If there is heavy rain (as from intense showers, slow-moving depressions) handling shall stop immediately; (iv) If sustained heavy rainfall (e.g. ≥10mm in 24 hours) occurs during soil stripping operations, work must be suspended and not re-started until the ground has had at least a full dry day or agreed moisture criteria (see below) can be met; (v) Soil shall not be handled or trafficked during or shortly after heavy precipitation (including rain, snow and hail) in a waterlogged condition, and when there are pools of water on the ground surface; and (vi) After rainfall has ceased, field tests shall be applied to determine when handling may re-start *Reason: To prevent damage to soils.*

9.2 Construction Phase

Soil Storage

All topsoil and subsoil shall be stored in accordance with document *(insert ref.)* dated *(insert date)* and in separate mounds which shall: (a) Not exceed 3 metres in height in the case of topsoil, or exceed 5 metres in height in the case of subsoil unless otherwise agreed in writing with the Local Planning Authority; (b) Be constructed with only the minimum amount of soil compaction to ensure stability and shaped so as to avoid collection of water in surface undulations; (c) Not be subsequently moved or added to until required for restoration unless otherwise agreed in writing by the Local Planning Authority; (d) Have a minimum 3.0 metre standoff, undisturbed around each storage mound;

(e) Comprise topsoils on like texture topsoils and subsoils on like texture subsoils;

(f) In the case of continuous mounds, ensure that dissimilar soils are separated by a third material, which shall have previously been agreed in writing by the Local Planning Authority.

Reason: To prevent the loss of soil and minimise damage to soil structure during storage.

Prior to soil stripping and formation of storage mounds, a scheme for grass seeding and management of all storage mounds that will remain in situ for more than three months shall be submitted for the written approval of the Local Planning Authority. Seeding and management of the storage mounds shall be carried out in accordance with the approved details.

Reason: To protect mounds from soil erosion, prevent build up of weeds in the soil and remove vegetation prior to soil replacement

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Within three months of completion of soil handling operations in any calendar year, the Local Planning Authority shall be supplied with a plan showing:

(a) The area stripped of topsoil, subsoil and soil making material;

(b) The location of each soil storage mound; and

(c) The quantity and nature of material therein.

Reason: To facilitate soil stock taking and monitoring of soil resources

9.3 Temporary Compound Decommissioning

Soil Replacement

Soil material shall be placed in accordance with the approved scheme. Any alteration to this working method shall only be carried out with prior approval from the Planning Authority.

The soil material (topsoil and subsoil) set aside for use in the agricultural restoration shall be spread uniformly and in correct sequence.

The soil profile in all areas restored to agricultural after use shall be in accordance with the approved scheme. Any intention to alter this soil depth will require prior approval from the Planning Authority.

All operations to move and place soil material shall be carried out only when such material is in dry and friable condition and ground conditions are dry and firm. The developer shall give 48 hours notice to the Planning Authority of the intention to carry out any soil movement operation, and no movement of soils shall occur:

(a) During the months May to October (inclusive), unless otherwise agreed in writing with the Local Planning Authority; and,

(b) Topsoil and subsoil handling for the restoration of land to agriculture, shall cease during rain, applying the following criteria:

(i) If there is light rain or drizzle, handling can proceed for up to four hours unless the soils are already in too moist a state (see tables below);

(ii) If there is light rain, handling will cease if the rain has not stopped in 15 minutes;

(iii) If there is heavy rain (as from intense showers, slow-moving depressions) handling shall stop immediately;

(iv) If sustained heavy rainfall (e.g. ≥10mm in 24 hours) occurs during soil stripping operations, work must be suspended and not re-started until the ground has had at least a full dry day or agreed moisture criteria (see below) can be met;

(v) Soil shall not be handled or trafficked during or shortly after heavy precipitation (including rain, snow and hail) in a waterlogged condition, and when there are pools of water on the ground surface; and

(vi) After rainfall has ceased, field tests shall be applied to determine when handling may re-start

The site shall be restored only in accordance with the approved *(insert ref)* Plan and all items therein shall be maintained to the satisfaction of the Planning Authority for a period of 5 years. Maintenance shall include the re-seeding of any areas of grassland that are in unsatisfactory condition in the view of the Planning Authority.

Reason: To ensure that the site is reclaimed in an orderly manner to a condition capable of maintaining the BMVAL[11] status.

All structures, buildings, debris and mounds shall be removed from the site on completion of permission. Compounds and access tracks shall be ripped and any resulting spoil removed from the site and the access removed unless otherwise agreed in writing with the Local Planning Authority.

9.4 Decommissioning Phase End of Life

Soil Replacement

Soil material shall be placed in accordance with the approved scheme. Any alteration to this working method shall only be carried out with prior approval from the Planning Authority.

The soil material (topsoil and subsoil) set aside for use in the agricultural restoration shall be spread uniformly and in correct sequence.

The soil profile in all areas restored to agricultural after use shall be in accordance with the approved scheme. Any intention to alter this soil depth will require prior approval from the Planning Authority.

All operations to move and place soil material shall be carried out only when such material is in dry and friable condition and ground conditions are dry and firm. The developer shall give 48 hours notice to the Planning Authority of the

[11] Best and Most Versatile Agricultural Land

intention to carry out any soil movement operation, and no movement of soils shall occur: (a) During the months May to October (inclusive), unless otherwise agreed in writing with the Local Planning Authority; and, (b) Topsoil and subsoil handling for the restoration of land to agriculture, shall cease during rain, applying the following criteria: (i) If there is light rain or drizzle, handling can proceed for up to four hours unless the soils are already in too moist a state (see tables below); (ii) If there is light rain, handling will cease if the rain has not stopped in 15 minutes; (iii) If there is heavy rain (as from intense showers, slow-moving depressions) handling shall stop immediately; (iv) If sustained heavy rainfall (e.g. ≥10mm in 24 hours) occurs during soil stripping operations, work must be suspended and not re-started until the ground has had at least a full dry day or agreed moisture criteria (see below) can be met; (v) Soil shall not be handled or trafficked during or shortly after heavy precipitation (including rain, snow and hail) in a waterlogged condition, and when there are pools of water on the ground surface; and (vi) After rainfall has ceased, field tests shall be applied to determine when handling may re-start The site shall be restored only in accordance with the approved *(insert ref)* Plan and all items therein shall be maintained to the satisfaction of the Planning Authority for a period of 5 years. Maintenance shall include the re-seeding of any areas of grassland that are in unsatisfactory condition in the view of the Planning Authority. *Reason: To ensure that the site is reclaimed in an orderly manner to a condition capable of maintaining the BMVAL status.*
All structures, buildings, debris and mounds shall be removed from the site on completion of permission. Compounds and access tracks shall be ripped and any resulting spoil removed from the site and the access removed unless otherwise agreed in writing with the Local Planning Authority.

Aftercare

An agricultural aftercare scheme outline strategy shall be submitted for the written approval of the Local Planning Authority at least three months before spreading of subsoil commences. The strategy shall provide for: (a) The physical characteristics of the land to be restored, as far as it is practical to do so, to what they were when the land was last used for agriculture; (b) A five year period of aftercare, specifying the steps to be taken and the period during which they are to be taken, and who will be responsible for taking those steps. The scheme shall include provision of a field drainage system; (c) A detailed annual programme, to be submitted to the Local Planning Authority *Reasons: To ensure the land is capable of retaining its BMVAL status.*
Before the start of the calendar *year* and every subsequent year during the aftercare period, the operator shall provide the Local Planning Authority and the landowner/occupier with a detailed annual programme for the approval of the Local Planning Authority including: (a) Proposals for managing the land in accordance with the rules of good husbandry including planting, cultivating, seeding, fertilising, draining, watering or otherwise treating the land for the forthcoming 12 months; (b) A record of aftercare operations carried out on the land during the previous 12 months. *Reasons: To ensure the productive afteruse of the land.*
Before *(insert date)* of every year during the aftercare period, unless otherwise agreed with the Local Planning Authority in writing, a site meeting shall be arranged by the operator, to which the Local Planning Authority and the landowner/occupier *(including the Welsh Government)* shall be invited to monitor previous performance and to discuss and agree future aftercare proposals. The meeting shall also be attended by the person(s) responsible for undertaking the aftercare steps. *Reasons: To ensure the productive afteruse of the land.*
Aftercare operations shall be carried out in accordance with the submitted aftercare scheme unless otherwise agreed in writing with the Local Planning Authority. *Reasons: To ensure the productive afteruse of the land.*

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APPENDIX 1 – Project Brief

Soil Policy Evidence Programme SPEP 2021-22/03

The impact of solar photovoltaic (PV) sites on soil and agricultural land quality.

VERSION 2 (Draft)

Introduction:

Solar photovoltaic (PV) sites started commercial distribution in the UK in 2007. The number of solar photovoltaic sites in the UK has increased from c. 1700 in 2010 to just over one million in 2019 https://www.statista.com/statistics/418830/number-of-solar-photovoltaic-installations-uk/.

It appears there has not been any systematic review of the impact of these sites on agricultural land, Best and Most Versatile (BMV) land and associated soils. The SPIES project is useful background though soil does not feature heavily https://www.lancaster.ac.uk/spies/. Similarly, the Armstrong *et al* (2016) paper: *Solar park microclimate and vegetation management effects on grassland carbon cycling* https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016 is useful background.

Solar PV sites can involve significant soil disturbance in installation, operational phase and decommissioning. A recent proposed 34ha site in Wales involved 70,000 solar panels with 140,000 piles driven into the soil to 1.8 metres, 1.75km of access track and 3.5km Security fencing (boundary measurement), plus associated cabling. Because solar PV energy is relatively new, there are no UK examples of decommissioned sites.

There are questions on the reversibility of these sites back to agriculture and the longer term impact on associated land and soil. There are claimed improvements to some soil properties (e.g. increased carbon storage and improved soil structure). However, are these simply just short term for the period of the scheme?

The impact of mineral sites (e.g. sand and gravel extraction / restoration) is reasonably well understood and with field experience. This is not the case for solar PV sites, partly because the decommissioning timescales are long (c40 years) and the evidence does not yet exist. Can parallels could be drawn with other developments such as golf courses, gas pipelines, and pylons. Similarly, are there parallels with horticultural activities such as grubbing out orchards and glasshouse removal? What impacts do these have on soil, how are effects mitigated and how successful are restorations?

This review is to provide an evidence based assessment of the impact of solar PV sites on agricultural land, Best and Most Versatile (BMV) land and associated soils. The scope of the study should be within the UK but look to international experience where possible. The study will inform Welsh Government and Natural England specialists when dealing with solar PV applications.

The review could be used as evidence at planning appeals. Consequently, clarity and accessible is really important, despite the likely complexity of some technical content.

It is anticipated the work will form 4 work packages (WPs):

Work Package 1: Literature review

This work package will:

1. Identify and review any relevant research or experience related to impacts of solar PV developments (published or anecdotal) on land and soil, within the UK or internationally.
2. Identify and review any relevant research or experience, related to (e.g.) golf courses, glasshouse removal, grubbing out of orchards or similar developments / activities (published or anecdotal) on land and soil, within the UK or internationally.
3. Identify and review the key research and experience relating to mineral developments on land and soil, within the UK and internationally.
4. Host a virtual workshop with key soil specialists in the area and record key findings. The key outputs from this need to be recorded as part of the contract.
5. Summarise key findings in a clear and accessible format.

Work Package 2: Description of Solar PV site history and development stages

This work package is intended as a short and simply a statement of facts, rather than in depth interpretation:

1. Provide a summary history of solar PV sites development in the UK. This should include date introduced, number of sites over time and basic explanation of how solar PV sites work. It would be useful to know approximately how many applications there have been (split by UK country), some information on range of site size, preferred types of location, and whether cumulatively large amounts of BMV are likely to be involved. Is the average size of sites increasing?
2. Identify and summarise the main interventions to land and soil with solar PV sites at installation (e.g. pile driving, panel installation, cable laying, track-laying & fencing). Averages (e.g.) of piles / ha or metres of buried cable / tracks / ha would be useful as context. Use of case studies could help. It will be important to summarise the potential levels of disturbance and any differences between different types of site.
3. Identify and summarise the potential benefits and threats to land and soil during the operational phase of the site. Claimed benefits are (for example) topsoil carbon content increases and soil structure improvements.
4. Identify and summarise the main interventions to land and soil when decommissioning sites (e.g. soil disturbance linked with equipment removal).

Work Package 3: Review of Solar PV site impacts on land and soil:

This Work Package is the main review of impacts. It will largely be based on WPs 1 & 2.

1. Review and summarise the main threats to soil and land associated with solar PV site developments. This will need to assess commissioning and decommissioning phases. Assessment of impacts on BMV land - and its reversibility - will be very important.
2. Review and summarise potential effects (positive and negative) on soils during the active phase of the site. Claimed benefits are (for example) topsoil carbon content increases and soil structure improvements. Are such claims realistic and are they only likely to be short term for the duration of the active site? What are the effects of shading and changes in soil microbial activity and microclimates under the panels? Armstrong et al (2016) is useful background: https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016. What effect does 'rilling' have on soil loss / erosion, accelerated run-off and in creating differential areas of soil

wetness? A discussion of short term changes in soil properties vs long term physical limitations (as in ALC) would be useful. A summary of claimed benefits to soil from previous cases would be very helpful.

3. Review and summarise to what extent evidence supports solar PV sites are physically reversible to agriculture in the BMV and non BMV context. What are the main issues and what evidence is there to support this? What factors influence reversibility (e.g. soil handling conditions, monitoring, soil types & climate).
4. Discuss the parallels between mineral site restoration and solar PV site restoration? Are the two comparable or do significant differences exist?
5. Discuss the parallels with golf course or similar type developments or activities and their reversibility. Are these comparable or do significant differences exist? IN Wales, Technical Advice Note 6 "TAN 6" (para 6.2.2) - Planning for Sustainable Rural Communities says, *"once agricultural land is developed, even for 'soft' uses such as golf courses, its return to agriculture as best and most versatile agricultural land is seldom practicable".*
6. Discuss to what extent soil handling conditions, as part of the planning process, can mitigate or remove any threats to soil and land. Can BMV sites realistically be restored to BMV and what factors influence this? Again, differences between sites will be useful to discuss.

Work Package 4: Summary of key issues and recommendations for future work

Based on the above work packages:

1 Summarise the key findings from this work. A non-technical executive summary is needed.

2 Identify evidence / knowledge / experience gaps.

3 Recommend what future work is needed to better understand the impacts of solar PV sites on soil and land.

APPENDIX 2 – Evidence Provided by Solar Energy UK

Project	Details	Wales	Information on Construction Methodology, Mitigation Techniques	Visual evidence of imagery of site impacts during construction	Construction method statements	Soil Management Plans	Evidence of soil quality improving on sites	Evidence of decommissioning requirements and provisions made for existing projects	Any further comments?
Cleve Hill Solar Park	Graveney, Kent	No	**> 'Cleve Hill Solar Park - Outline Construction Environmental Management Plan'** **Access to document** https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010085/EN010085-001554-CHSP%20-%20D6%20-%206.4.5.4.pdf **Please take specific note to 3.4(64),4.3(78). 5.5(105), 6.1 (107,108,109) and Appendices, particularly appendix E which outlines LBMP construction mitigation measures. (Appendix E - LBMP)** **>'Cleeve Hill - Environment Statement'** **Access to document -** https://drive.google.com/drive/folders/1bKEBKmZv9SqFz4K8DAlElc80Bz-1gDTF **Please take specific note to 5.5.4**		**Updates to existing documents outline construction environmental management plan revision E'** **Access to document -** https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010085/EN010085-001554-CHSP%20-%20D6%20-%206.4.5.4.pdf			> '**Cleve Hill Solar Park - Environmental Statement'** 9.5.2.6 Deposition of dust 171. Fugitive dust emissions and track-out dust during construction and decommissioning have the potential to affect ecological receptors. Chapter 16: Air Quality of the ES provides an assessment of the potential effects of the impacts of dust emissions and track-out dust. The assessment concluded that in the absence of mitigation, there was a low risk of dust soiling to ecological receptors as a result of the earthworks and trackout and a negligible risk from the construction works (building of substation, control building, battery storage units, transformers and solar panel installation). Decommissioning effects were assessed to be similar in nature and no greater than those predicted for the construction phase.	**Full Preliminary Environmental Information Report can be accessed here.** https://drive.google.com/drive/folders/1lE-fACqMlJCzrf9v0dn8DYUed6WY9xU9
Botwwnog Solar Farm	Gwynedd, 5MW	Yes	**'Soils and Agricultural Land Classification'** **Access to document - as**		**Construction Method Statement - (Proposed)**	**Soils and Agricultural Land Classification'** ***Document sent**			**Landscape and Visual Impact Assessment -** **Access to document - see zip file.**

			attached. **Please pay particular reference to 7.3.1, 7.3.2,7.3.3**		**Access to document as attached.**	**as attachment*** **Please pay particular notice to 2.2.1,**			**Please pay particular notice to chapter 7 (7.1.1-7.1.5) and chapter 10.**
Bypass Solar Farm	Lincolnshire49.9MW	No	**Ecological Impact Assessment Report Access to document** http://bypassfarmsolar.com/documents/update110920/12904_r01a_eia_as_mm_210820_compressed.pdf**Please pay particular attention to:**(4.12,4.36) No solar panels are proposed adjacent to watercourse WC1, or within the RPA of hedgerows and trees, minimising the potential for impacts to this habitat. However, the ditch and hedgerows within the site could be affected during construction by soil compaction from machinery, which could impact on the root systems, and/or by accidental damage. As such, they will be fenced and protected during construction in accordance with best practise guidance detailed in BS 5837:2012 'Trees in relation to design, demolition and construction'(British Standard, 2012) to reduce potential for impacts and accidental damage., , page 21)**Flood Risk AssessmentAccess to the document** http://bypassfarmsolar.com/documents/update110920/14516_hyd_xx_xx_rp_fr_0001_p02_bypass_farm.pdf **Please refer to page 9** of the assessment which outlines mitigation techniques			**Planning Statement, Proposed Solar farm, land at Bypass Farm, South of A1 Bypass** http://bypassfarmsolar.com/documents/update110920/bypass_farm_solar_planning_statement_v3.pdfPlease take note to point **2.1.6**			**Full planning documents can be found here** http://bypassfarmsolar.com/downloads/

			regarding to construction and soil compacting/surface run off.						
Low Farm Solar Farm	West Yorkshire, 49.9MW		**Construction Traffic Management Plan'Access to the document** https://www.boom-power.co.uk/wp-content/uploads/2021/10/General_896661-17298-HYD-XX-XX-RP-TP-P004-Construction-traffic-management-plan.pdf**'Flood Risk Assessment & Drainage Strategy'You can access the document here**https://www.boom-power.co.uk/wp-content/uploads/2021/10/FloodRiskAssessment_896753.pdf**Please refer to point 5.2.2 'Planning Statement'Access Document** https://www.boom-power.co.uk/wp-content/uploads/2021/10/General_896701-Planning-Statement.pdf**Please take note to pages - 33,34,38, 46**			**Agricultural Land ClassificationAccess the document**https://www.boom-power.co.uk/wp-content/uploads/2021/10/General_896760-AGRICULTURAL-LAND-ASSESSMENT.pdf**Please pay particular attention - Page 12**		**Design and Access Statement Access Document** https://www.boom-power.co.uk/wp-content/uploads/2021/10/DesignandAccessStatement_896749.pdf Page 32Design and Access Statement https://www.boom-power.co.uk/wp-content/uploads/2021/10/DesignandAccessStatement_896749.pdf **Pay Particular attention to page 32**	
Eveley Farm	Stockbridge, Hampshire		See attachment	See attachment					
Llanwern	Newport, South East Wales	Yes	**'Land on Caldicot levels to the south of Llanwern Steelworks site'** **Full document accessed here** https://dns.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/DNS/3213968/DNS-3213968-000525-Report%203213968%20(for		**'Local Impact Report'** **Full document can be accessed here** https://dns.planninginspectorate.gov.uk/wp-content/ipc/upl				**A full suite of planning documents can be found here** https://dns.planninginspectorate.gov.uk/projects/wales/llanwern-solar/?ipcsection=docs&stage=1

			merly%203150137).pdf **Please pay attention to points 127, 139, 240**		oads/projects/DNS/3213968/DNS-3213968-000525-Report%203213968%20(formerly%203150137).pdf **Please pay particular attention to the construction method statement on Page 27**				
Outside the UK									
Neoen Solar Farm	Australia	No				**Soil and Water Management Plan** https://parkessolarfarm.com.au/wp-content/uploads/2020/08/PL-EV-04-Soil-and-Water-Management-Plan-Rev2.pdf			

APPENDIX 4 – Solar Farm Construction Images

Site A

Figure 1

Figure 2

Figure 3

Site B

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

APPENDIX 5 – Impact of Soil Wetness Limitation

Table A shows the example of a **medium-textured soil** in **Wetness Class I** before commissioning, classified as BMV land and then **disturbed** during construction, the interaction of climate (FCD) and the depth to an introduced slowly permeable layer.

Where there is evidence of an SPL starting within 60 depth cm reference is made to Figure 7 of the ALC Guidelines (MAFF, 1988) and where there is an SPL starting between 60 cm and 80 cm depth reference is made to Figure 8 of the ALC Guidelines (MAFF, 1988).

Table A Residual Impact of Introduced SPL on ALC Grade- Medium -texture soil

FCD	Pre-construction		Post-decommissioning		
	Wetness Class	ALC Grade	Depth to introduced SPL	Wetness Class	ALC Grade
230	I	3a	0 to 25 cm	V	4
		3a	25 to 60 cm	IV	3b
		3a	60 to 80 cm	III	3b
225	I	2	30 to 60 cm	IV	3b
		2	60 to 80 cm	III	3a
170	I	1	35 to 46 cm	IV	3b
		1	46 to 60 cm	III	3a
		1	60 to 80 cm	II	2
125	I	1	35 to 60 cm	III	3a
		1	60 to 80 cm	II	2

Table B shows the example of a **medium-textured soil** in **Wetness Class I** before commissioning, classified as BMV land and **undisturbed** during construction, the interaction of climate (FCD) and the depth to an introduced slowly permeable layer. Where there is evidence of gleying within 40 cm depth and an SPL within 80 cm depth reference is made to Figure 7 of the ALC Guidelines (MAFF, 1988). Where there is gleying within 70 cm depth and an SPL within 80 cm depth reference is made to Figure 8 of the ALC Guidelines (MAFF, 1988).

Table B Residual Impact of Introduced SPL on ALC Grade- Medium- textured soil

FCD	Pre-construction		Post-decommissioning			
	Wetness Class	ALC Grade	Depth to introduced SPL, with gleying <40 cm	Depth to introduced SPL, with gleying >40 cm	Wetness Class	ALC Grade
230	I	3a	0 to 25 cm		V	4
			25 to 62 cm		IV	3b
			62 to 80 cm		III	3b
				0 to 80 cm	III	3b
225	I	2	25 to 61 cm		IV	3b
			61 to 80 cm		III	3a
				28 to 80 cm	III	3a
170	I	1	35 to 46 cm		IV	3b
			46 to 74 cm		III	3a
			74 to 80 cm		II	2
				35 to 60 cm	III	3a
				60 to 80 cm	II	2
125	I	1	35 to 62 cm		III	3a
			62 to 80 cm		II	2
				35 to 42 cm	III	3a
				42 to 80 cm	II	2

Table C shows the example of **a light-textured soil** in **Wetness Class II** on **disturbed land** and the residual impact of an introduced SPL (caused by unremediated subsoil compaction) on BMV agricultural land.

Where there is evidence of an SPL starting within 60 depth cm reference is made to Figure 7 of the ALC Guidelines (MAFF, 1988) and where there is an SPL starting between 60 cm and 80 cm depth reference is made to Figure 8 of the ALC Guidelines (MAFF, 1988).

Table C Residual Impact of Introduced SPL on ALC Grade- Light- texture soil

FCD	Pre-construction		Post-decommissioning		
	Wetness Class	ALC Grade	Depth to introduced SPL	Wetness Class	ALC Grade
230	II	3a	0 to 25 cm	V	4
		3a	25 to 60 cm	IV	3b
		3a	60 to 80 cm	III	3b
225	II	2	25 to 60 cm	IV	3b
		2	60 to 80 cm	III	3a
170	II	1	35 to 46 cm	IV	3a
		1	46 to 60 cm	III	2
		1	60 to 80 cm	II	1
125	II	1	35 to 60 cm	III	2
		1	60 to 80 cm	II	1

Table D shows the example of a **light-textured soil** in **Wetness Class II** on **undisturbed land** and the residual impact of an introduced SPL (caused by unremediated subsoil compaction) on BMV agricultural land.

Where there is evidence of gleying within 40 cm depth and an SPL within 80 cm depth reference is made to Figure 7 of the ALC Guidelines (MAFF, 1988). Where there is gleying within 70 cm depth and an SPL within 80 cm depth reference is made to Figure 8 of the ALC Guidelines (MAFF, 1988).

Table D Residual Impact of Introduced SPL on ALC Grade- Light-texture soil

FCD	Pre-construction		Post-decommissioning			
	Wetness Class	ALC Grade	Depth to introduced SPL, with gleying <40 cm	Depth to introduced SPL, with gleying >40 cm	Wetness Class	ALC Grade
230	II	3a	0 to -25 cm		V	4
		3a	25 to 62 cm		IV	3b
		3a	62 to 80 cm		III	3b
		3a		0 to 80 cm	III	3b
225	II	2	35 to 61 cm		IV	3b
		2	61 to 80 cm		III	3a
		2		35 to 80 cm	III	3a
170	II	1	35 to 46 cm		IV	3a
		1	46 to 74 cm		III	2
		1	74 to 80 cm		II	1
		1		35 to 60 cm	III	2
		1		60 to 80 cm	II	1
125	II	1	35 to 61 cm		III	2
		1	61 to 80 cm		II	1
		1		35 to 42 cm	III	2
		1		42 to 80 cm	II	1

ISEP
Impact Assessment

SOLAR PV ON AGRICULTURAL LAND

Essential Components of Environmental Assessments and Reports

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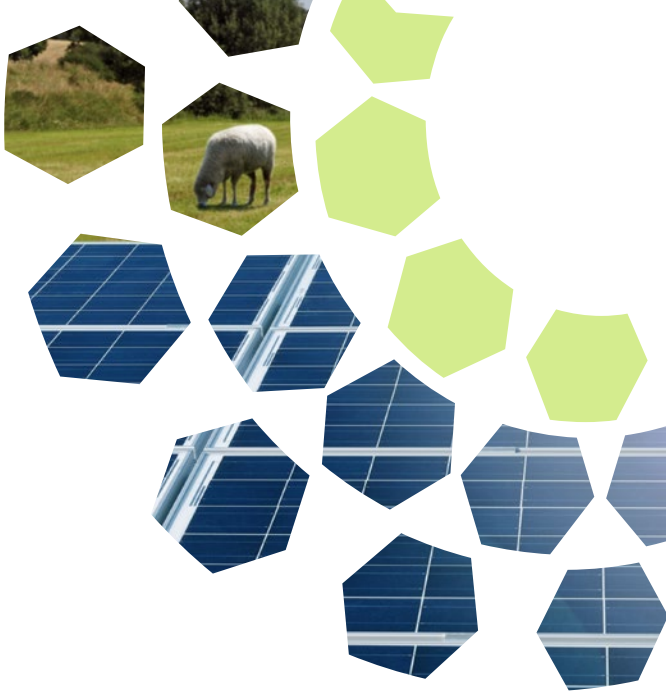
ABBREVIATIONS AND ACRONYMS

AFBI	Agri-Food and Biosciences Institute
ALC	Agricultural Land Classification
BMV	Best and Most Versatile (agricultural land classification)
BRE	Building Research Establishment
BSSS	British Society of Soil Sciences
CEA	Cumulative Effects Assessment
CEMP	Construction Environment Management Plan
CPRE	Council for the Preservation of Rural England
DCO	Development Consent Order
Defra	Department for Environment, Food and Rural Affairs
DMPO	Town and Country Planning (Development Management Procedure) (England) Order
DMRB	Design Manual for Roads and Bridges
EIA	Environmental Impact Assessment
EOR	Environmental Outcomes Report
EU	European Union
EV	Electric Vehicle
GW	Gigawatt (of energy)
ICE	Institute of Civil Engineers
LandIS	Land Information System (Soil data for England and Wales)
LCA	Land Capability for Agriculture (Survey)
LPA	Local Planning Authority
MAFF	Ministry of Agriculture, Fisheries and Food
MAGIC	Multi-Agency Geographic Information for the Countryside
MW	Megawatt (of energy)
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
PV	Photovoltaic
SEA	Strategic Environmental Assessment
SMP	Soils Management Plan
SRP	Soil Resource Plan

1

SOIL AND SOLAR



1 SOIL AND SOLAR

Scope

The government has recently set out plans to enhance the country's energy security and deliver clean power by 2030[1] to support the wider push towards net-zero by 2050. As part of these plans, it has committed to delivering 47 gigawatts (GW) of solar by 2030; nearly tripling the existing 15 GW. As a result, there will be a significant increase in the number, size and scale of solar developments seeking planning consent.

The Planning and Infrastructure Bill, introduced in 2025, will bring changes to the Nationally Significant Infrastructure Project (NSIP) regime, notably to the consultation requirements, aimed at ensuring quicker delivery of infrastructure projects. No changes are currently proposed to the content of Environmental Impact Assessments (EIAs) for NSIPs.

This guidance has been produced in response to current inconsistencies in EIAs and Strategic Environmental Assessments (SEAs) for large-scale solar photovoltaic (PV) projects on agricultural land, of a sufficient size to be NSIPs. It is also applicable to projects that are below the NSIP threshold, but for which an EIA may be required by the Local Planning Authority (LPA).

NSIPs are determined in accordance with the decision-making framework in the Planning Act 2008 (as amended) and relevant National Policy Statements (NPSs) for major infrastructure. For soils and agricultural land, they follow the general approach of the 2024 revision of the National Planning Policy Framework (NPPF)[2]. Although the wording of the devolved NPSs may differ slightly, the general approach is that poorer-quality agricultural land should be used in preference to that of best and most versatile (BMV) quality land in England, Wales and Northern Ireland or prime land in Scotland; any impacts on soil quality should be minimised; and for developments on previously developed land, applicants should ensure that they have considered the risk posed by land contamination.

Further guidance is provided in the Overarching National Policy Statement for Energy (EN-1)[3] and the National Policy Statement for Renewable Energy Infrastructure (EN-3)[4]. These state that where the proposed use of any agricultural land has been shown to be necessary, poorer-quality land should be preferred to higher-quality land (avoiding the use of BMV land where possible). While the development of ground-mounted solar arrays is not prohibited on BMV land, the impacts of such are expected to be considered. Applicants should explain their choice of site, noting the preference for development to be on suitable brownfield, industrial and low- and medium-grade agricultural land. Additionally, applicants are encouraged to develop and implement Soil Resource and Soil Management Plans, which could help to use and manage soils sustainably and minimise adverse impacts on soil health and potential land contamination. This should be in line with the ambition set out in the Environmental Improvement Plan to bring 40% of England's agricultural soils into sustainable management by 2028 and increase this to 60% by 2030.

[1] NESO (2024). Clean Power 2030
[2] Ministry of Housing, Communities and Local Government (2025). National Planning Policy Framework
[3] Department for Energy Security and Net Zero (2023). Overarching National Policy Statement for Energy (EN-1)
[4] Department for Energy Security and Net Zero (2023). National Policy Statement for Renewable Energy Infrastructure (EN-3)

Mitigation measures for agricultural soils include use of green cover, multispecies cover crops (especially during the winter) minimising compaction and adding soil organic matter.

Projects for solar PV range from those covering a few hectares (ha) to large schemes covering hundreds of hectares, including some in excess of 1,200 ha. Following the revision of the latest NPPF, LPAs will be responsible for renewable and low carbon energy development of 100 megawatts (MW) or less installed capacity, which typically occupy up to 150 ha. Renewable and low carbon developments of over 100 MW capacity, classed as NSIPs, are considered by the Secretary of State for energy and net-zero via a Development Consent Order (DCO), and the affected LPAs are statutory consultees. These new thresholds are double those in the 2008 Planning Act.

The UK Government's 2015 Guidance for Renewable and Low Carbon Energy covers the planning of ground-mounted solar PV farms[5]. This includes the promotion of the use of non-agricultural land and, where a proposal involves greenfield sites, the use of poorer-quality land in preference to higher-quality land. The guidance allows for continued agricultural use where applicable and/or encourages biodiversity improvements around arrays. The current position is that solar arrays are temporary in nature, with the land restored to its baseline condition following decommissioning. Likewise, land use changes for statutory Biodiversity Net Gain (BNG) are to be retained for 30 years.

The BRE Trust has produced a guidance paper for agriculture on solar farms[6]. Opportunities for continued agricultural use mainly relate to grass-based systems for sheep and poultry, while beekeeping is another possibility. However, grassland and other agricultural land management may conflict with biodiversity objectives. There are also sections on land management during the operational phase, which covers the establishment and maintenance of an appropriate vegetation cover to prevent loss and/or damage to the soil resource.

Solar Energy UK has produced *Natural Capital Best Practice Guidance*[7] which includes guidance on incorporating measures to increase biodiversity and protect natural capital within solar developments, with sections on the establishment of a suitable vegetation cover and its maintenance during the operational phase.

Despite the above guidance, there is considerable inconsistency of approach among environmental consultants over the content and interpretation of the agricultural components of EIAs and planning applications for solar PV projects. An EIA is likely to be required for solar PV development in environmentally sensitive or vulnerable locations, and for most NSIPs, as set out in the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017[8].

Within the EIA process, the assessment of impacts considers the ability of land and soil to continue to fulfil its primary functions (eg. the production of food and biomass, supporting biodiversity within habitats and as a carbon sink). Accordingly, the impacts of solar arrays on land and soils are determined with reference to the maintenance of their functions during construction and operation, and on decommissioning, although impacts on soil health have become a further consideration.

An EIA should be objective and bespoke methodologies, which might be seen to favour the developer's case, should be avoided. This guidance provides a checklist of key matters to cover when assessing the effects of solar arrays on agricultural land, for use by developers and their consultants, planners and consultees. The checklist covers:

- Options Appraisal
- Soil and Agricultural Land Classification (ALC) or Land Capability for Agriculture (LCA) surveys
- Soil surveys for Soil Management Plans for both construction and decommissioning
- Post-decommissioning land management to maintain and enhance soil health and functions
- The pollution risk from damaged panels or their installation on already contaminated land
- Biodiversity Net Gain (BNG)
- Socio-economic impacts to the rural economy
- Cumulative effects.

[5] Ministry of Housing, Communities and Local Government (2023). Renewable and low carbon energy
[6] BRE Trust (2014). Agricultural good practice guidance for solar farms
[7] Solar Energy UK (2022). Natural Capital Best Practice Guidance
[8] Infrastructure Planning (Environmental Impact Assessment) Regulations 2017

Context

The wider context to this guidance is that the government is planning to replace EIAs and SEAs with Environmental Outcomes Reports (EORs[9]). This reform of the environmental assessment regime in parts of the UK may alter the ways in which assessments are undertaken and reported. Irrespective of whether future assessments focus on impacts or outcomes, this Advice Note will assist practitioners assessing the implications of solar developments on agricultural land.

Therefore, this guidance has been drafted as an interim measure during a possible transitional period, to be compatible with the objectives of the SEA, EIA and EOR processes in relation to solar developments. The desired outcome of all these environmental assessment processes is to inform decision-making to assist the eventual return of farmland to agriculture in good condition.

This guidance reflects our present understanding of the impacts and effects of solar development on soils and agricultural land use. As more solar projects progress and more data are gathered on the impacts and effects and potential for mitigation that arise in practice, this Advice Note will be adjusted in light of that new evidence.

The focus is on how to facilitate the reversibility of solar PV, by maintaining flexibility of agricultural land use and avoiding damage to soil quality. Soil practitioners are already aware of the broader impacts arising from some solar farm infrastructure, such as access tracks and the footprints of hard standings for built structure and cabling. ADAS has produced a report for the Welsh Government on the impact of solar PV sites on agricultural soils and land quality[10]. This considers soil compaction, benefits of carbon capture and soil disturbance on decommissioning through the removal of anchors. However, the full impacts of solar PV are not yet understood. For example, the installation of structures supporting solar panels might cause subsoil compaction, but in the absence of any decommissioning studies it is not possible to determine the nature or significance of this potential impact. Also, it is possible that the operational maintenance of solar panels might lead to repeated replacements and upgrades which increase mechanised activities in and around solar arrays.

Recent events at Porth Wen on Anglesey, when solar panels were destroyed by strong winds ,have shown that significant contamination by broken glass and chemical pollution can arise because of exceptional weather events that may be on the increase.

Therefore, initial practical guidance is required at a time when soil practitioners have had limited opportunities to understand these impacts, how to avoid them, and their significance. This understanding will be achieved through a greater emphasis on monitoring land use and soil surveys carried out by independent and competent specialists during the aftercare management period that should follow decommissioning. The evidence on reversibility will be provided by comparing the results of these surveys with the original baseline surveys, together with the commissioning of research projects.

Further enhancement of reversibility would be provided by supplementing a construction Soil Management Plan (SMP), with a post-decommissioning, preferably independent, soil audit.

[9] GOV.UK (2023). Environmental Outcomes Reports: a new approach to environmental assessment.
[10] ADAS (2023). 2020/21 Soil Policy Evidence Programme: The impact of solar photovoltaic (PV) sites on agricultural soils and land quality

National Policies within the United Kingdom

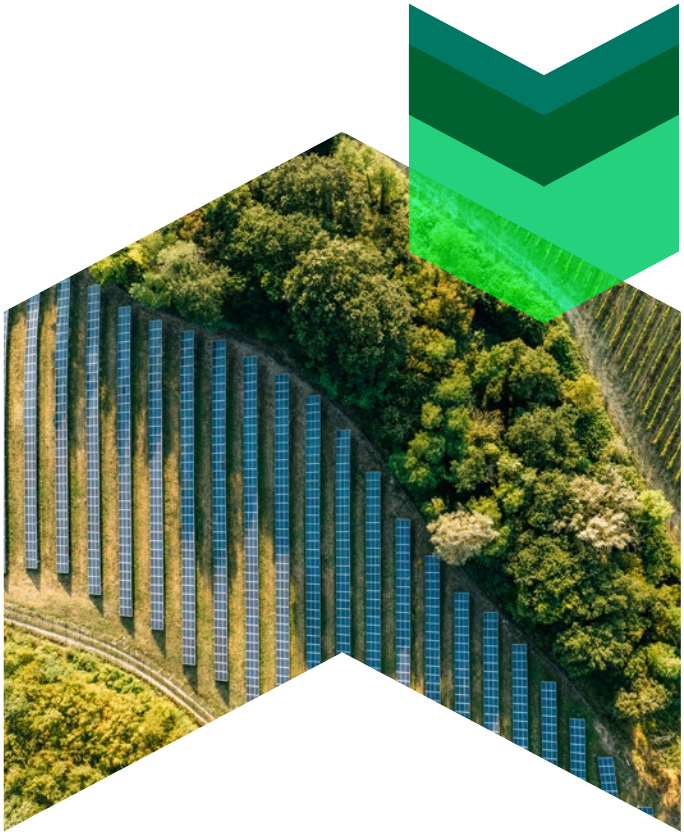
Across Great Britain and Northern Ireland there are different national policies for granting planning permission for solar arrays on agricultural land, particularly regarding the use of best and most versatile (BMV) land in England and Wales, or prime land in Scotland. However, this Advice Note is applicable throughout the UK, despite these policy differences. National policies are summarised in the Annex.

EIA Checklist for Solar Arrays/Panels

The checklist in Box 1 is to address what this Advice Note considers to be the main deficiencies in EIAs produced for solar projects.

Box 1: EIA checklist for solar arrays/panels

- Soil/ALC surveys carried out at less than the required 100 m sampling density and not to the required 120 cm depth (where possible)
- Lack of representative soil pit descriptions to supplement auger data
- Lack of reference to relevant published soil data to verify and supplement the results of the soil/ALC/LCA surveys
- Lack of identification of the potential soil contamination risks from damaged panels (including broken glass) and proposals for remediation
- Incomplete assessment of the socio-economic impacts of a large-scale solar PV, such as displacement of tenant farmers and redundancy of the agricultural workforce
- Lack of clarity as to how the condition of the land will be assessed after decommissioning and its suitability for farming
- Lack of clarity as to how any BNG during operation might be retained on decommissioning, if the land is returned to farming



Options Appraisal

The consideration of alternatives (locations, types of development and layout of infrastructure) and setting out reasons for selection of the preferred option is a recommended part of the SEA. As illustrated in Figure 2 of ISEP's *A New Perspective on Land and Soil in Environmental Impact Assessment* (accessible only through ISEP membership). The effects of solar arrays on soils and agriculture are among many considerations in an Options Appraisal.

An Options Appraisal, although not a legal requirement for an EIA is, nevertheless, desirable. Where a number of sites have been under consideration, some justification for the final selection is helpful to the planning process.; for example, alternative site assessment will typically be required for any planning application relating to inappropriate development in the green belt.

Where a landowner is the developer, with only a single plot of land, for which they are applying permission for, they may argue that identification of alternative sites is not realistic. However, even in these scenarios, the consideration of alternative design options in relation to the site characteristics is appropriate.

An appraisal of options with regard to soils and agriculture should take into account not only the ALC/LCA classification but also the sensitivity of soils to handling, and the maintenance of soil quality (in respect of loss of soil volumes, mixing topsoil and subsoil, and compaction etc) and the presence of valuable farm infrastructure (such as a dairy unit), which would not be evident from ALC/LCA alone. The British Society of Soil Science (BSSS) has a guidance document on sourcing additional soil and land quality information, such as archived data at Cranfield University[11]. While these considerations may necessarily be qualitative, their inclusion in any comparison of potential sites or design options should demonstrate whether the development of a chosen site will have a lesser effect on soil, land and agriculture (including farm businesses) than the alternatives, subject to other considerations. Further relevant guidance on site selection is available from Natural England (2022)[12] and the Institute of Quarrying[13].

Much of the agricultural component of the Options Appraisal will be desk-based, supported by site visits, using soil and ALC or LCA maps and data obtainable from Natural England[14], [15], Defra's MAGIC[16], the Welsh Government's Predictive ALC Map[17], LandIS[18] and Scotland's soils website[19].

Box 2: Agricultural checklist for the Options Appraisal[20]

- If land of poorer quality is available locally, why was it not selected for the solar array?
- Where suitable soil information is available, how do the soils compare with others locally in terms of ease of handling and restoration?
- What is the risk of carbon loss or fugitive greenhouse gas emissions during the construction and operational phases of development, relative to other sites assessed?
- Is there valuable farm infrastructure (such as a dairy unit or an irrigation system), which would not be evident from ALC/LCA alone?

Soil and ALC/LCA Surveys and Soil Handling

The most recent EIA guidance for agricultural land and soils is in ISEP's 2022 guidelines *A New Perspective on Land and Soil in Environmental Impact Assessment*[21]. Consideration of the development impacts on the soil resource and soil function should be made alongside agricultural land-take. Alternatively, published methodologies are contained in DMRB LA109 *Geology and Soils*[22], the Institute of Civil Engineers (ICE) *EIA Handbook*[23] from which much of the ISEP methodology is derived, and Defra's Code of Practice for the sustainable use of soils on construction sites[24].

[11] British Society of Soil Science (2022). Guidance Document 2: Soils and Land Quality: How to find online maps and data sets
[12] Natural England (2022). Guide to reclaiming mineral extraction and landfill sites to agriculture
[13] Institute of Quarrying. Soils Guidance
[14] Natural England. Regional Agricultural Land Classification Maps
[15] Natural England. Agricultural Land Classification detailed Post 1988 ALC survey
[16] Defra. MAGIC map
[17] Welsh Government. Agricultural land classification: predictive map
[18] LandIS. Soil data
[19] Scotland's soils. soils.environment.gov.scot
[20] ISEP (2022). A New Perspective on Land and Soil in Environmental Impact Assessment
[21] *Ibid.*
[22] Standards for Highways (2019). LA 109 - Geology and soils
[23] Institute of Civil Engineers (ICE) (2019). Environmental Impact Assessment Handbook
[24] Defra (2011). Code of practice for the sustainable use of soils on construction sites

The Council for the Preservation of Rural England's (CPRE) paper, Decision-making in land use planning and the Agricultural Land Classification System, that argues the ALC system is outdated, particularly in terms of climate data and land degradation, and requires revision[25]. It suggests that while a revision might reduce the amount of BMV land, it could add to the value and hence the need to better protect what remains. However, any likely revision is some way off and the existing ALC/LCA classifications should continue to be adhered to.

All agricultural land in England and Scotland and all predicted BMV land in Wales which may experience temporary or permanent disturbance as a result of physical development should be subject to a detailed ALC or LCA survey.

For EIA scoping, the sources of published and other information on soils and land quality should be specified. Natural England specifies that during the actual assessment, detailed surveys are to be carried out at a minimum density of one auger bore per hectare[26]. Soils should be described using the *Soil Survey Field Handbook*, which is the national standard for soil descriptions[27]. Representative profile pits for each of the main soil types within a study area should be excavated and examined to assess certain soil properties, including soil structure and stone content, in greater detail. The surveys provide baseline data about the current condition of the site, which can be used by the assessor to identify and evaluate the likely significant effects (normally defined as moderate to very large) of the proposed development on the soils and to minimise the impact on BMV/prime agricultural land. As part of that process, the assessor should identify good practice soil handling methodologies, commonly known as a Soil Management Plan (SMP) or Soil Resource Plan (SRP), which will incorporated into the Construction Environmental Management Plan (CEMP) or Code of Construction Practice. This should be adopted to avoid or mitigate likely significant effects during site preparation and construction, the operational phase and restoration and aftercare. Guidance on this is contained in Defra's Code of practice for the sustainable use of soils on construction sites[24]. The surveys should also be used to inform siting of infrastructure within a project boundary, such as minimising use of BMV/prime land.

The collection of soil samples should be carried out at the same time as the ALC/LCA surveys to inform the nutrient status, soil organic matter and soil organic carbon content across the site. This will provide essential baseline information on the suitability of the land for its intended use/function, be it either agricultural or for BNG, and also inform suitable landscaping and seed mixes during the project operational phase. These data can then be used for site monitoring during operation and after decommissioning.

As already stated, large-scale solar PV is a relatively new land use. There is little available evidence concerning the effect of panels and their supporting structures on soil quality in the longer term, so there are different views on the significance of impacts. Therefore, this Advice Note proposes that, on decommissioning, an independent audit is conducted by competent soil scientists of the soil condition to assess its suitability for return to farming. The audit would look at topsoil and subsoil structure (for evidence of compaction), organic matter and nutrient status, and functioning of field drains. Where panels have been damaged, the audit should look for shards of glass or plastic in the topsoil that might harm grazing livestock and for chemical contaminants. The audit should specify any remedial work to be undertaken before farming recommences.

Soil Handling and Land Restoration

It is expected that soil survey information (for all soils, not just those of BMV/prime quality) is provided with the development proposal to inform soil handling, re-use and restoration, so that there is site- and soil-specific consideration for soil management. An outline Soil Management Plan (SMP), or Soil Management Scheme (SMS) in Wales, should be prepared in line with Defra's Code of Practice for the sustainable use of soils on construction sites[28]. The outline SMP/SMS will be expanded and incorporated into the Construction Environmental Management Plan (CEMP) and should include the following, outlined in Box 3 on the following page.

[25] CPRE (2025). Decision-making in land use planning and the Agricultural Land Classification System: stick, twist, or bust?
[26] Natural England (2021). Guide to assessing development proposals on agricultural land
[27] Hodgson J.M. (rev 2022). Soil Survey Field Handbook. Cranfield University.
[28] Defra (2011). Code of practice for the sustainable use of soils on construction sites

Box 3: Checklist to assess ALC/LCA survey and soil-handling methodologies

- Is the surveyor sufficiently qualified and experienced to undertake soil and ALC surveys and have they achieved full membership of the British Society of Soil Science, or an equivalent professional body?
- Has the survey methodology been agreed with key stakeholders?
- Has the survey used Revised guidelines and criteria for assessing the quality of agricultural land (MAFF, 1988) to determine ALC grade?
- Are the soils described according to the *Soil Survey Field Handbook*[29]?
- Was the field survey work correctly carried out, such as auger borings at a density of one per hectare, representative sample pits, laboratory samples and is there an annex containing complete horizon descriptions and wetness and droughtiness calculations?
- Have the survey results been checked against existing soil and ALC surveys at or close to the site, such as those available on LandIS and the MAGIC website? Have any important differences been accounted for?
- Has an assessment of ALC and/or soil resources of the site been undertaken before work commences to inform the EIA, soil handling and restoration?
- Were soil handling methodologies, including soil storage where required, tailored to site-specific soil resources?
- Is mitigation, including reference to Defra's construction Code of Practice[30], tailored to site-specific soil resources?
- Is there a methodology by which the applicant intends to restore affected areas to agricultural use and base line ALC/LCA grade/class on decommissioning?
- Is there an aftercare programme which would enable a satisfactory standard of agricultural after-use to be reached, with regards to cultivating, reseeding, draining or irrigating, applying fertiliser, or cutting and grazing the site?

Pollution Risk from Damaged Solar Panels and Legacy Soil Contamination

The scope, methodology and competency requirements for assessing contaminated land risks for new development and planning applications are well established in UK legislation, guidance and planning procedures[31].

In an EIA report, this topic may be included in the agricultural chapter or within a separate one. Either way, it has a bearing on agricultural land quality.

Potential pollutants contained in panels (depending on age and model) include arsenic, cadmium, tellurium, lead, hexavalent chromium, copper and selenium. It should be demonstrated in the EIA that solar panels have been considered as a potential source of pollution being introduced to agricultural land. If damage occurs during installation, operation or decommissioning, this would require appropriate mitigation that should be specified in the EIA.

Physical and chemical damage to panels could result from a number of events including breakages during installation and decommissioning, machinery strikes, high winds, hail stones, stone chippings from nearby haul routes and leakages from weathering. Receptors at risk are human and livestock health, surface water and groundwater, and property.

Stages of Assessment

The cause for concern with regards to potential land contamination during solar farm construction and operation would be determined with reference to the baseline set by the previous agricultural use of the land and surrounding area (eg. made ground, pesticides and herbicides use, buried waste etc) and with the potential for new sources of contamination being introduced during construction.

The process that must be followed for contaminated land site investigation and risk assessment as part of EIA can be summarised as several stages. Not all stages are required for every project, as some sites may not necessitate investigation beyond the desk-based assessment.

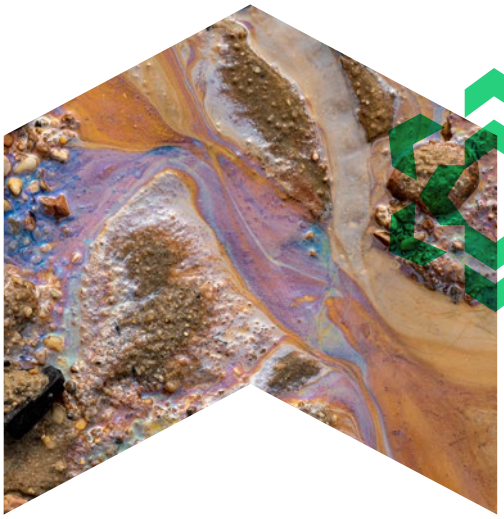
[29] Soils Survey Field Handbook. Hodgeson, J.M. (1975) Soil Survey Field Handbook. Rothhamsted Research
[30] Defra (2011, updated 2018). Code of Practice for the Sustainable Use of Soils on Construction Sites.
[31] Ministry of Housing, Communities and Local Government (2019). Land affected by contamination

It is not always the case that the stages can be delivered in the order outlined below (eg. submission of the Environmental Statement could be before remediation and verification are completed, provided an acceptable plan is in place and agreed with the relevant stakeholders):

1. **Desk-based review** of published information to establish the likelihood of there being contaminated land risks. This is done by identifying potential sources of contamination (existing from legacy land use as well as potentially introduced with the proposed development), the receptors at risk of exposure to the sources (existing and introduced human health, property, controlled waters) and whether there are existing pathways or pathways that could be introduced to connect the sources to the receptors.
2. **Ground investigation, geo-environmental monitoring and detailed risk assessment.** Findings of the desk-based assessment inform the requirement and scope for site investigation. This could include exploratory holes and sampling and monitoring of soil, water, ground gases and vapours. The findings are used to inform a detailed risk assessment.
3. **Remediation and verification.** The findings of the detailed risk assessment inform the requirements for remediating any existing contamination. Verification of the site being suitable for its proposed use is completed once remediation has been carried out.
4. **Informing the EIA.** The above steps are used to confirm the assessment stages required in the EIA, and the findings of the assessments are used to identify the significance of effects.
5. **Mitigation and monitoring for EIA.** Once existing contamination has been dealt with to an acceptable level, mitigation measures are listed in the EIA to reduce risks from source-pathway-receptor connections being established during the lifecycle of the proposed development. This may include pollution response plans, environmental management plans, toolbox talks, good housekeeping and on-going monitoring of geo-environmental conditions.

Box 4: Checklist for pollution risk assessment on agricultural land

- Agriculture is a potential on-site source of contamination in a contaminated land assessment (burial/burning of waste, localised made ground, pesticide and herbicide use), and so intrusive site investigation may be recommended by the desk study.
- If the desk study concludes that no significant contamination is likely to be present, there may not be a requirement to carry out soil sampling and analysis to further assess risk and so this topic can be scoped out.
- However, regardless of risk, soil samples and baseline analysis will be beneficial in the event of a pollution incident occurring during construction, operation or decommissioning, and is worth implementing to confirm the land's baseline condition.
- Such a baseline could also be used to establish soil health and thus aid any remediation at the end of the site's use for solar.
- Panels could be damaged during installation, operation or decommissioning and it should be demonstrated in the EIA that this been considered as a potential introduced source of pollution.
- Appropriate mitigation, in the event of pollution, should be identified in the EIA and any Soil or Environmental Management Plan submitted with the EIA.
- The maintenance and auditing plans during operation should be robust and include the regularity of checks proposed to be carried out.



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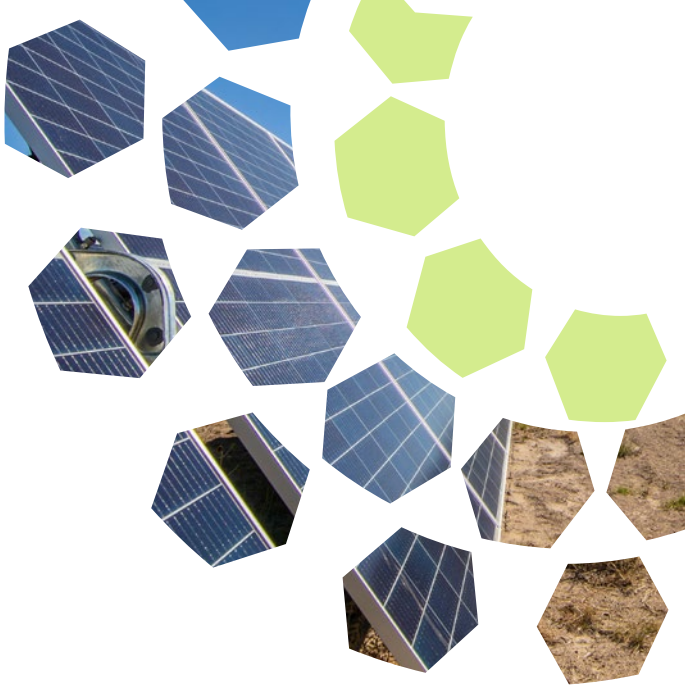
OTHER IMPACTS FOR SOLAR DEVELOPMENT ON AGRICULTURAL LAND



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OTHER IMPACTS FOR SOLAR DEVELOPMENT ON AGRICULTURAL LAND

Biodiversity Net Gain (BNG)

The Environment Act 2021[32] mandates that solar development sites, including NSIPs, should provide net biodiversity gain of at least 10% after May 2026. BNG introduced by solar projects must be sustainable for at least 30 years, which is the design life of most solar farms. BNG distribution should be carefully considered in the context of land quality and future farming operations and, where necessary, should be located off-site to maintain the best-quality land, usually BMV or prime.

Solar development proposals commonly allow for continued, albeit limited, agricultural use (grazing, beekeeping etc) and it is feasible for well-designed projects to deliver BNG in close proximity to those arrays, for instance by establishing species-rich ground cover. The current policy balance generally favours biodiversity over food production, resulting in often large areas of BNG within the solar developments, on land not actually covered by arrays. These might include open wildflower meadows and woodland planting, which are likely to be retained, should this emphasis be maintained at decommissioning. In which case, this should be recognised as a policy driven semi-permanent loss of agricultural land use rather than an unavoidable consequence of solar farms. In some circumstances this will apply to BMV or prime land, although it is preferable that BNG be directed towards lower-quality land within solar farm sites that include BMV or prime land.

In order to deliver solar developments that deliver the best biodiversity outcomes with minimal future permanent loss of land for food production, each solar development site's Biodiversity Management Plan (BMP) should consider how BNG can be delivered using existing features such as hedgerows, wet and dry ditches, field margins and temporary wet areas, as well as through the creation of pollen and nectar strips between panels, before advocating the semi-permanent removal of land from production.

Where it proves necessary to use the most productive land for BNG, consideration should be given to creating BNG through improving field boundary features such as hedgerows and ditches and establishing permanent conservation headlands or wetter areas where individual ephemeral ponds can be encouraged. Where sufficient BNG cannot be found on-site, without resort to taking productive land for the creation of a wildflower meadow or establishment of a woodland, consideration should be given to the inclusion of suitable opportunities for BNG off-site, using field boundaries and poor land/habitat in place of productive agricultural land.

The adoption of this protocol will help minimise the long-term loss of productive agricultural land.

[32] Environment Act 2021

Notes on Soil Health

At the time of writing, there is no established methodology for the incorporation of soil health assessment into an EIA (for recently published guidance see ISEP's *Soil Health and Environmental Assessment*) and given the spatial variation and weather dependency of some of the indicators, this is best done at farm scale. Therefore, soil health checks could be suitable for a solar PV, particularly at decommissioning, when any remediation measures can be identified. As such, it could form part of the decommissioning soil audit proposed by this Advice Note within the SMP.

This information would lead to the development of an evaluation methodology to determine the sensitivity of soil health indicators/receptors, together with the magnitude and significance of impacts to inform a statutory environmental assessment.

In response to these challenges, ISEP is publishing a Soil Health Advice Note that sets out an initial evaluation methodology to determine the sensitivity of soil health indicators/receptors, together with the magnitude and significance of development effects to inform a statutory environmental assessment.

The main influences on soil health are through agricultural land management and the land use changes and effects on soils arising from development. These Advice Notes are concerned with the latter. Currently, the effects of development on soil are assessed with reference mainly to the soil physical properties determining soil functions.

In the State of the environment report for soil[33], the Environment Agency defined soil health as, 'the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans', and this recognises the relationship between soil health and soil functions. Soil functions will be at their optimum level when soils are in good health. However, measuring soil health is complex, because of the natural variability of soil and the need to consider soil biology, as well as the physical properties of soils. The problem is that parameters for biological and chemical properties are more difficult to set, observe, sample and record in the field. They are also more variable over short distances and over time than soil physical properties, making it difficult to get representative soil samples.

As a relatively new concept, soil health is now frequently referred to in an environmental planning context, but only in broad terms, and there is a need to ensure that it can be considered meaningfully to promote development that protects or improves soil functions and health. The complexity and our limited understanding of soil health requires a simplified and generalised approach, and this means that assessment of development effects on land and soils is likely to continue to be based mainly on soil functions, with some scope to supplement environmental assessment guidelines to include the consideration of soil health.

To do this we need to understand the likely effects of land use changes on the soil properties that determine soil functions and soil health, and to consider how recorded changes to these indicators/receptors of soil health caused by solar farms can be integrated into environmental assessment methodologies.

We need to develop better information on soil health, on indicators/receptors such as the level of humus and biological activity in the soil, earthworm counts, and other soil invertebrates known to be essential for good soil health, and these could be measured at a project scale. Other possible approaches to measuring soil biodiversity receptors include measuring plant root density and microbial populations.

This information would lead to the development of an evaluation methodology to determine the sensitivity of soil health indicators/receptors, together with the magnitude and significance of impacts to inform statutory environmental assessment.

[33] Environment Agency (2019). State of the environment: soil

Socio-economic Impact Assessment

The ISEP's *A New Perspective on Land and Soil in Environmental Impact Assessment* only considers the potential environmental impacts and does not provide a methodology for assessing these socio-economic impacts, but there are established ones in the DMRB LA 112 Population and human health[34] and in the HS2 *EIA Scope and Methodology Report*[35].

In addressing socio-economics, it is important to note the December 2024 NPPF[36] has removed consideration of the availability of agricultural land for food production from the planning process.

There is no consistency in how socio-economics are covered in EIAs for solar projects. Sometimes there is an Agricultural Circumstances chapter covering farming interests, and in others there is a Population and Human Health chapter. The intrinsic relationship between the soil, crops and the people who work with both could, perhaps, justify a standalone chapter to address soils and agriculture in their own right.

Landowners are compensated through commercial agreements. However, the EIA should consider the socio-economic impacts of displacement of tenant farmers, agricultural workers, and the impact on land-take on the continued viability of affected farms and wider local agricultural economy. This requires full farm Impact Assessments, based on meetings with landowners and long-term tenants.

Displacement of tenant farmers and agricultural workers is a socio-economic impact and where there is a cluster of large solar arrays there may be a cumulative downstream socio-economic impact on the local agricultural supply industry such as seed, fertiliser and feed merchants, and agricultural contractors. On the beneficial side, there may also be new opportunities for employment and business associated with solar power plants that benefit the local economy.

Where landowners are bought out by compulsory purchase (as is permissible for NSIPs) the financial compensation is not an environmental mitigation and so cannot influence the residual effect of loss of part or all of a farm business. However, where the landowner is a willing participant in the solar scheme, then their share of the income from electricity generation (normally the rental value) can be considered as mitigation, as the solar farm is a form of diversification of the farm business.

Box 5: Checklist for socio-economic assessment

- Farm holdings affected – size and proportion to be taken out of agriculture
- Land use and annual loss of output
- Tenant farmers to be displaced
- Workforce to be displaced
- Loss of business for agricultural suppliers
- Employment and business opportunities generated by the solar project

Cumulative Effects Assessment

The requirement for Cumulative Effects Assessment (CEA) is set out in the Environmental Impact Assessment Directive (EIA Directive 2014/52/EU[37]). However, as is recognised by ISEP's A New Perspective on Land and Soil in Environmental Impact Assessment (Annex H), an agreed methodology for the CEA on land and soils has yet to be established, but helpful guidelines are provided there. Some of ISEP's key points are summarised here, but reference should be made to the original document, where useful worked examples are provided.

There are two types of cumulative effect on agricultural land, and these can be described as:

- All effects on land and soil arising from a proposed development
- These effects in combination with other developments at the national and local levels.

The first type is encompassed by the second, which gives the full significance of cumulative losses of land used for agriculture and soil.

[34] Standards for Highways (2020). LA 112 - Population and human health
[35] HS2 (2017). EIA Scope and Methodology Report
[36] Ministry of Housing, Communities and Local Government (2025). National Planning Policy Framework
[37] European Commission. Environmental Impact Assessment

Effects on Land and Soil

The temporary nature of solar PV has been challenged, given the uncertainty arising from their anticipated 30- to 40-year operational life. On cessation of operations and following sustainable decommissioning, solar PV could be considered a temporary land use that does not contribute to cumulative losses of land in agricultural uses. However, with the grid connection infrastructure already in place, it is tempting to assume that a new solar farm would be created on the site, unless technological advances greatly reduce future project footprints. This is part of the current uncertainty in respect of planning applications for NSIP solar farm projects, with a number of potentially influential inquiry decisions yet to be made.

Taking a precautionary approach, however, and given the current policy emphasis on BNG, solar farms are likely to lead to a semi-permanent reduction in land used for agriculture. However, to put this into context, currently solar farms occupy less than 0.1% of the UK's land, according to data presented by Solar Energy UK (a solar industry trade body)[38]. To meet the government's net-zero target, the Climate Change Committee estimates that we will need 90 GW of solar by 2050 (70 GW by 2035), which would mean solar farms would at most account for approximately 0.6% of UK land. On the other hand, CPRE, in July 2025, pointed out that 59% of England's largest operational solar farms are located on productive farmland, principally in the arable East of England, where almost a third (31%) of the area they cover is classified as the nation's BMV agricultural land[39].

Cumulative effects on land and soil are generally related to loss of land, soil and soil functions, and may be adverse or beneficial. As these are finite and non-renewable resources, all such effects, where permanent are likely to be significant. For permanent effects and with reference to ISEP's A *New Perspective on Land and Soil in Environmental Impact Assessment* (Annex H), the degree of significance should ideally be determined with reference to the contribution of individual development projects to changing rates of land losses at the national level on a rolling five-year basis. However, this would require databases yet to be established.

As an interim measure, it should be feasible for solar projects to look at other projects locally and nationally, which is an exercise that is relatively easy, at least for NSIPs (see next section).

Effects in Combination with Other Developments

According to ISEP, this should cover the direct and indirect effects of reasonably foreseeable developments on soil functions and ecosystem services over wider areas at national and local levels. In assessing this category of cumulative impacts, it is necessary to clearly define spatial and temporal parameters for a development project, together with other 'reasonably foreseeable' developments that can include those listed in the box below:

Box 6: Checklist of cumulative effects in combination with other developments

- Development under construction
- Permitted applications (full or outline), not yet implemented
- Submitted application(s) not yet determined
- Projects on the Planning Inspectorate's Programme of Projects
- Polar allocations identified in the Local Development Framework (and emerging Core Strategies and Allocations Plan) and their equivalents in Wales, Scotland and Northern Ireland – with appropriate weight being given as they move closer to adoption
- Developments identified in other plans and programmes which set the overall framework

[38] Solar Energy UK (2024). Fact Sheet: Solar Farms and Agricultural Land 2024.
[39] CPRE (2025). Two-thirds of mega solar farms built on productive farmland

ANNEX: NATIONAL POLICIES AFFECTING SOLAR DEVELOPMENT IN THE UNITED KINGDOM

Defra and Natural England

Under the Town and Country Planning (Development Management Procedure) (England) Order 2015 (DMPO), Natural England is a statutory consultee on development that involves the loss, or could lead to the loss, of over 20 ha of BMV agricultural land (land graded as 1, 2 and 3a in the ALC system), where this is not in accordance with an approved plan.

The Department for Environment, Food and Rural Affairs (Defra) is the policy lead in England, with Natural England's role to provide competent and impartial advice on the impact of a development proposal on agricultural land quality, to enable LPAs to make informed decisions. Current Defra/Natural England advice is set out in a *Guide to assessing development proposals on agricultural land*[40].

Natural England assesses each proposal on its merits and advises the planning authority about whether there is likely to be a significant loss in agricultural land quality. Solar PV applications should be supported by a detailed ALC survey, using the 1988 revised guidelines[41]. The assessment will, amongst other things, take account of the baseline agricultural land quality, the reversibility (without loss of land quality) of any earthworks and the scale, duration and location of any such development.

As described above, solar development proposals commonly allow for continued, albeit limited, agricultural use and/or promise biodiversity improvements around arrays, and the relevant primary legislation for Biodiversity Net Gain (BNG) is the Environment Act 2021[42].

Another issue with returning land to farming after 40 or so years is where an irrigation licence is currently held. If abstraction ceases over a period of years, the Environment Agency will withdraw a dormant licence. Should it be reapplied for, on decommissioning of the solar array, it is likely that reservoir storage will be required to support abstraction, but even then the competition for water in the drier eastern counties for urban and industrial use would not guarantee a new licence being granted.

Natural England typically advise LPAs to apply conditions to secure appropriate agricultural land management and biodiversity enhancement during the lifetime of the development, as well as securing its decommissioning and restoration to its former condition and ALC grade when planning permission expires. It is acknowledged that in most cases there will be a reduction in the intensity of production during operation; for example, where there is a change from intensive arable to a grassland system. In this context, it is important to note that the current agricultural use of the land does not necessarily reflect the ALC grade, nor does the grade reflect the current economic value of the land.

Applications for smaller solar projects, previously less than 50 MW, now 100 MW, do not go through the DCO process and are submitted to the LPA. Recent experience is that the stance taken by LPAs on use of agricultural land varies across England. Applications have been turned down on the grounds of loss of BMV land and its implications for food production, among other concerns, while other LPAs consider that the provision of renewable energy should take precedence. Refused applications may be taken to appeal or 'called in' by the Secretary of State.

Scotland's Local Government and Housing Directorate

Solar arrays in Scotland, to date, are small in scale, mainly below 25 MW on sites smaller than 40 ha. However, there is growing interest in larger-scale arrays to take advantage of the long summer daylight hours. The National Planning Framework 4[43], published in February 2023, provides the national spatial strategy for Scotland, setting out the spatial principles, regional priorities, national developments and national planning policy.

Policy 42 sets the *Policy Principles for Soils*, which are then put in place at the local level through the Local Development Plans (LDP) from each planning authority.

[40] Natural England (2021). Guide to assessing development proposals on agricultural land
[41] Natural England (1988). Agricultural Land Classification of England and Wales: Revised criteria for grading the quality of agricultural land (ALC011)
[42] Environment Act 2021
[43] Scottish Government (2023). National Planning Framework 4

Policy 5b states: Development proposals on prime agricultural land within the Land Capability for Agriculture Classification (LCA) system or land of lesser quality that is culturally or locally important for primary use, as identified by the LDP, will only be supported in particular cases. These include the generation of energy from renewable sources or the extraction of minerals and there is secure provision for restoration.

It should be noted the current agricultural use of the land does not necessarily reflect the LCA grade, nor does the grade reflect the current economic value of the land.

NatureScot has issued pre-application and scoping advice for solar farms that aims to assist applicants, developers and consultants involved in preparing applications and Environmental Impact Assessment (EIA) reports (where these are required) for such developments[44]. It also provides advice on opportunities for mitigation and enhancement including grazing and biodiversity between the panels. Thus, the position in Scotland is similar to that of England. Solar developments would be permitted on the best-quality (prime) land, provided a credible restoration plan is presented by the developers.

Welsh Government and its Land Quality Advisory Service

ALC surveys are required to be undertaken by developers where the Welsh Government's Predictive ALC Map shows a likelihood of BMV land[45]. Because BMV land is scarce in Wales, much emphasis is placed on its protection. The Welsh Government's Land Quality Advisory Service (LQAS) will provide advice on survey requirements and validate ALC surveys for LPAs, surveyors and developers free of charge. This service allows the determining authority to have confidence in the information being presented. Should any party refuse or neglect to commission a survey, or the survey is not accepted by the Welsh Government, the Predictive Map Grade should be accepted as the best available information for the purpose of determination.

Solar PV applications in areas likely to be BMV land should be supported by a detailed ALC survey, together with a Soil Resources and Physical Characteristics Report for all soils (including non-BMV) impacted by the proposed development.

As in England and Scotland, the current agricultural use of the land does not necessarily reflect the ALC grade, nor does the grade reflect the current economic value of the land.

Solar applications have been refused on the basis that BMV land should only be developed if there is an overriding need for the development and either previously developed land or land in lower agricultural grades is unavailable, or available lower-grade land has an environmental value which outweighs the agricultural considerations.

The Welsh Government has commissioned a report (in preparation) to investigate *The impact of solar photovoltaic (PV) sites on agricultural soils and land*. This is investigating the implications of the wet climate of Wales on the reversibility of soil compaction incurred during construction, operation and decommissioning of solar arrays, and whether, in some cases, compaction may be permanent, leading to loss of versatility. However, in the absence of any decommissioning studies it is not possible to consider empirical evidence to determine the significance of the potential compaction impacts.

Additionally, in respect of solar PV developments on BMV, of importance is a letter to chief planning officers issued by the Minister for Climate Change on 1 March 2022:

Should solar PV array applications on BMV agricultural land come before the Department for Climate Change, the Department will object to the loss of BMV agricultural land unless other significant material considerations outweigh the need to protect such land in accordance with Welsh Government policy and guidance.

Northern Ireland

Existing solar EV developments on agricultural land are small, the largest in 2025 being a 46 MW array on the Bann Road in County Antrim. Policies for the protection of agricultural land and consultation on rural planning matters are the responsibility of Defra, but there are no published guidelines specific to EIAs for solar arrays in Northern Ireland.

The soils of the whole of Northern Ireland have been mapped at a scale of 1:50,000 and, in addition, there is a 1:250,000 scale map of the province, all obtainable from the Agri-Food and Biosciences Institute (AFBI)[46].

The ALC system is the same as that of England and Wales, subdividing Grades 3 into A and B (but capitalised), with Grades 1, 2 and 3A being classed as BMV. There is no comprehensive coverage of provisional or detailed ALC maps, so the classification for a specific piece of land is determined by reference to the published soil maps, or by ordering a report from the AFBI, for which there may be a charge.

[44] NatureScot (2025). NatureScot pre-application guidance for solar farms
[45] Agricultural land classification: predictive map (Wales)
[46] Agri-food and Biosciences Institute. Soil maps and soil survey

ISEP
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Wilder Ecology
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Literature review

Impacts of ground mounted solar farm/parks on biodiversity

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1 Introduction

1.1 Purpose and scope

This report has been prepared by SWT Trading Ltd: Wilder Ecology, the ecological consultancy of the Suffolk Wildlife Trust, for The Wildlife Trusts. Here we discuss the current scientific evidence for the impact of solar farms on biodiversity, what evidence there is on positive and negative impacts, where best practice is documented and where we still have knowledge gaps.

1.2 Background

Within the United Kingdom (UK) the development of ground mounted solar has rapidly expanded over the past two decades partly due to incentive schemes and to policy changes; the Climate Change Act (and net zero ambitions), and the National Planning Policy Framework. Solar farms are now projected to grow substantially across the UK to meet the commitment of net zero by 2050 and a 68% reduction in emissions by 2030.

Currently data at the end of April 2025 demonstrates there is a total of 18.1GW of solar capacity in the UK, this is an increase of 5.9% (1.0GW) since April 2024 (DESNZ, 2025). The UK government target for solar capacity by 2035 is 70GW (GOV.UK, 2022) which requires a huge increase from the current level. To meet the national solar energy targets solely with ground-mounted solar schemes could require 0.9-1.4% of land in England the area of up to 180,000 hectares (CPRE, 2023). This could have a huge impact both on natural habitat and reduction of land used for agriculture. Nature positive guidance on design of solar farms is required to enable an enhancement of biodiversity in these essential schemes.

An additional consideration when aiming to deliver this solar capacity is compliance with the Environment Act (2021), which requires a mandatory minimum of 10% biodiversity net gain from the baseline level for solar farms. Furthermore, the development of the emerging Local Nature Recovery Strategies (LNRS) could make alignment of solar projects with the proposed strategic areas complex when seeking planning approval.

Solar farms have been typically designed and managed only to produce renewable electricity (Nordberg et al, 2021; Jarčuška et al, 2024) however there is a rapidly advancing shift in focus

particularly within the UK to provide ground-mounted solar farms that are multifunctional aiming to enhance biodiversity and/or provide ecosystem services whilst harnessing solar power.

1.3 Definitions of key terms

For clarity within the review the following terms have been defined as below:

- Nature positive solar farm design – a design that integrates solar infrastructure with both ecological restoration and biodiversity enhancement
- Ground mounted solar – free standing solar panels at ground level, not at higher elevation
- *Solar park – large scale installation of solar panels
- *Solar farm – solar installation generally smaller than solar park

*these terms were found to be completely interchangeable within this research

1.4 Aims

This report was commissioned to explore and review the relevant evidence published regarding the design of solar farms in terms of biodiversity considerations. The aims of this literature review are to identify:

a) Published evidence on the impact of ground mounted solar on biodiversity
b) Any best practices or guidance
c) Any gaps in research

Summaries of the data found and important gaps in evidence are identified and future research recommendations made.

2 Methodology

2.1 Review of published articles

The scope of the literature review was defined as:

- Subject matter restricted to ground mounted solar panels and biodiversity
- Focusing on UK studies – or those in similar temperature geographical locations
- Articles in English
- Articles that have been published within the years 2015-2025

A literature search was undertaken in the subsequent order using Google Scholar, Science Direct and JSTOR for research papers between 2015 and 2025, published in English, sorted by relevance. Publish or Perish (Harzing, 2016) was utilised to analyse and assess publications returned.

2.2 Search terms

A trial search term was conducted to narrow down results to fit to the aims of the research:

- ("ground mounted solar" OR "solar farm" OR "solar park") AND 'biodiversity' AND ('UK' OR 'United Kingdom')

This term revealed in excess of 1000 results; therefore the search term was altered. The following search term became the initial search term; 'ground mounted solar' to narrow down the terminology for the solar infrastructure design relevant to the research aims. Boolean operator 'AND' was used to combine the solar infrastructure with the *feature* 'biodiversity', finally restricting results with 'AND' ('UK' OR 'United Kingdom').

Initial search term:

("ground mounted solar") AND biodiversity AND ('UK' OR 'United Kingdom')

Following this initial first search further searches were conducted using different *features* 'habitat', 'wildlife', 'birds', 'bats' ('insects' OR 'invertebrates').

2.3 Review of grey literature

The searches included both primary and review articles, in addition any grey literature such as relevant government or non-governmental organisations reviews and technical reports were accessed. References within review articles were also accessed to expand the number of sources of literature assessed. This enabled a larger data set of articles to be reviewed.

2.4 Citation chaining

Where a lack of primary studies was located, a process of backward citation chaining was used whereby the references cited in the primary source were reviewed to provide additional resources. In addition to this forward chaining was also conducted to locate those that have cited the relevant article.

2.5 Copilot, Semantic Scholar and google search

An additional search was conducted using Copilot, Semantic Scholar and general google with the same initial search term:

("ground mounted solar") AND biodiversity AND ('UK' OR 'United Kingdom'). The first 10 pages of results by relevance were accessed.

2.6 Artificial Intelligence statement

AI tools (Semantic Scholar and CoPilot) were used to assist with identifying, screening and locating literature for this review. All subsequent analysis of relevant articles were conducted by human reviewers to ensure methodological rigour. All interpretations and summary reporting were solely conducted by the researcher.

3 Results

3.1 Overall results

A total of 226 articles were identified across the databases from the primary search ('ground mounted solar') AND biodiversity AND ('UK' OR 'United Kingdom'). Of those 8 were duplicated in the within Google Scholar, then 18 in the second and 3 in the third database search leading to 198 unique articles. These 198 articles were assessed and 41 of those were found relevant to the search criteria. Grey literature and citation chaining added a further 15 relevant articles. Semantic Scholar, Copilot and Google searches returned a further 8 relevant documents generating a total of 64 published documents for final review.

Table 1. Initial search results

Search Order	Database	No of results	No of duplicate records	No of new relevant articles
1	Google Scholar	184	8	37
2	Science Direct	38	18	4
3	JSTOR	4	3	0

3.2 Publication year

Sources of publications were focussed to the past 11 years 2015-2025, and of the 64 articles in the final selection over two thirds, 66% were generated within the past 4 years, this year being only 6 months through.

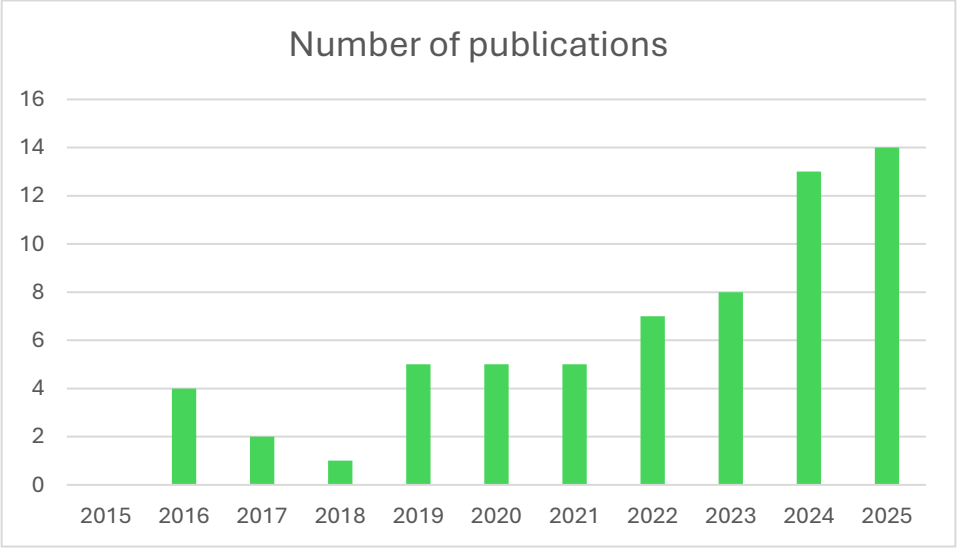

Figure 1. Number of publications/year

3.3 Primary data sources UK

The table below details the sources of available data from studies conducted in the UK.

Table 2. Biodiversity features specifically addressed within UK – primary data/guidance

Features	*Details*	*Supporting Literature*
Biodiversity - general	Planning application review - BNG	Benouzid and Simon (2025)
	Management approaches	Esteves (2016)
	Determinants of planning	Hussain et al (2025)
	Comparative study biodiversity	Montag et al (2016)
	Biodiversity enhancements - guide	Parker and Monkhouse (2022)
	Guidance document - monitoring	Solar Energy UK (2022)
	Locations of solar farms	Tinsley et al (2024)
Habitats	Grassland - review	Carvalho et al (2024)
	Local climate effects - grassland	Makaronidou (2020)
	Grassland	Stott (2022)
Ecosystem services	Honeybee – pollinator dependent crops	Armstrong et al (2021)
	Combined land use - pollinators	Blaydes et al (2025)
	Combined land use – food production	Copping et al (2024)
	Combined land use - agrivoltaics	Neesham-McTiernan (2025)
	Combined land use	Oudes et al (2021, 2022)
	Combined land use	Randle-Boggis et al (2020)
Soils	Soil carbon	Carvalho et al (2024)
	Soil responses	Carvalho et al (2025)
Botany	Plant responses	Carvalho et al (2025)
	Grassland and broadleaved diversity	Montag et al (2016)
Birds	Impacts on breeding birds	Copping et al (2024)
	Management impacts – breeding birds	Copping et al (2025)
	Species abundance and diversity	Montag et al (2016)
Bats	Bat activity/species richness	Montag et al (2016)
	Bat activity data	Tinsley et al (2023)
Invertebrates	Pollinator diversity	Armstrong et al (2021)
	Pollinator diversity	Blaydes et al (2021)
	Pollinator diversity	Blaydes et al (2022)
	Bumblebee populations	Blaydes et al (2023)
	Invertebrate diversity and abundance	Montag et al (2016)

3.4 Overall impacts

The table below details the positive and negative impacts observed on each feature identified from global data sources.

Table 3. Positive and negative impacts identified

Features	*Positive impacts*	*Negative impacts*
Biodiversity - general	Benouzid and Simon (2025)	Ashaf et al (2024)
	Esteves (2016)	Matwani & Ojija (2025)
	Hussain et al (2025)	
	Montag et al (2016)	
Habitats	Carvalho et al (2024)	Guoqing et al (2021)
	Lambert et al (2023)	Makaronidou (2020)
		Xu et al (2024)
Ecosystem services	Adeh et al (2019)	Guoqing et al (2021)
	Armstrong et al (2021)	Hernandez et al (2019)
	Blaydes et al (2025)	
	Hernandez et al (2019)	
	Ludzuweit et al (2025)	
	Tölgyesi, C., et al (2024)	
	Treasure et al (2025)	
Soils	Cesar et al (2025)	Carvalho et al (2025)
	Zhao et al (2025)	Cesar et al (2025)
	Zheng et al (2023)	Lambert et al (2024)
		Makaronidou (2020)
		Neesham-McTiernan (2025)
		Uldriji et al (2023)
		Stott (2017)
		Zhao et al (2025)
		Zheng et al (2023)
Botany	Lambert et al (2023)	Carvalho et al (2025)
	Montag et al (2016)	Cesar et al (2025)
	Randall-Boggis et al (2019)	Hernandez et al (2020)
		Xu et al (2024)
Birds	Barn Owl Trust (2025)	Montag et al (2016)
	Copping et al (2025)	Harrison et al (2017)

	Jarčuška, et al (2024)	Smallwood et all (2022)
	Montag et al (2016)	Walston et al (2016)
	Yuzyk (2024)	
Bats	Montag et al (2016)	Barre et al (2023)
	Szabadi et al (2023)	Harrison et al (2017)
	Szoldatits et al (2025)	Montag et al (2016)
		Smallwood et all (2022)
		Szabadi et al (2023)
		Szoldatits et al (2025)
		Tinsley et al (2023)
Invertebrates	Armstrong et al (2021)	Egri et al (2016)
	Barley et al (2025)	Farkas et al (2016)
	Blaydes et al (2021)	Grodsky et al (2024)
	Blaydes et al (2022)	
	Montag et al (2016)	
	Tölgyesi, C., et al (2024)	
	van der Haas (2019)	

3.5 Review of impacts

The impacts resulting from the reviewed publications were categorised for discussion into the following categories:

- Impacts on biodiversity
- Impacts on habitats/soils/vegetation
- Impacts on ecosystem services
- Impacts on bats
- Impacts on birds
- Impacts on invertebrates
- Previous overall impact literature reviews
- Biodiversity Net Gain
- Guidance and information on design and management
- Research gaps and future directions

4 Discussion/Review of the literature

Impacts on biodiversity

The impacts of solar farms on biodiversity have been addressed by numerous researchers in a variety of areas; some addressing a particular taxa, element or geographic area, some comparing solar facility types and others more broadly combining a selection of taxa to indicate a measure of biodiversity. The key UK focussed biodiversity wide study is described below:

Montag et al (2016) conducted a comparison study of 11 solar farms in the southern region of the UK. They detail that where solar farms actively implement management focussing on wildlife there can be an increase of biodiversity demonstrated across a number of different species. They detailed that management including; utilising a diverse seed mix, conservation grazing/mowing, limiting herbicide use and inclusion of marginal habitats all add to botanical diversity. This botanical diversity then leads to greater abundance and diversity of butterflies, bumblebees and other invertebrates which then makes provision further up the food chain for other species such as birds and bats. The location of solar farms generally within a wider agricultural landscape makes them a haven for other species particularly birds of conservation concern with the ability to provide a mosaic of habitats. During this study the habitat was noted to also have been valued by brown hare, an area that warranted further research.

Many other studies in the UK evidenced solar farms as an opportunity to increase biodiversity on site as part of the specific subject matter they were addressing (Armstrong, et al 2021; Blaydes et al, 2021; 2022; 2023; 2025; Benouzid & Simon, 2025; Esteves, 2016; and Husain et al, 2025).

Impacts on habitats/soils/vegetation

Habitat types have been addressed within the literature with a dominance of focus on grassland and agricultural land sitings of solar facilities. In addition to that several studies have looked at the impact of solar farms on soils, hydrology and vegetation.

Some positive impacts included a study by Randall-Boggis et al (2019). The species richness of plants, grasses and eudicot species was found to be significantly higher in the solar parks where management actions had been applied compared with control sites and varied with the action prescribed. Another positive impact was found by Lambert et al (2023) where in tilted tracking photovoltaic systems grassland habitats could be enhanced by improving the water uptake thereby promoting vegetation restoration.

Soils is an area of research that has expanded rapidly however the conclusions are not consistent with each other (Zhao et al, 2025) and impacts of the geographic location of the solar facility not necessarily comparable (Zheng et al, 2023). Negative impacts were detailed by Carvalho et al (2025) where they sampled 32 solar farms across the England and Wales quantifying plant cover, soil nutrients and physiochemical properties of areas of land under and between solar panels as well as on control land adjacent. Plant mass was significantly lower underneath the panels than between or on control land. Soil compaction was also found to be higher under the panels, and the soil organic carbon and particulate organic matter was also lower under the panels. Soil nitrogen was higher under the panels, as was phosphorous. Insights from this on the soil health of solar farms can assist in design and management of options for enhancing both plant cover and soil carbon storage at solar farms in future. However, the previous land use was highlighted as a major factor in the progression of the potential of the land. Previous findings from Makaronidou (2020) were very similar – cooler air and soil temperatures, higher soil moisture content under panels creating local climatic effects. Stott (2017) found both decomposition and productivity under solar panels was suppressed. Uldrijan et al (2023) found solar panels created extreme soil conditions and vegetation responds by increasingly being dominated by tolerant species, opening up opportunity for invasive species. Lambert et al (2024) also found negative impacts on soils in an experimental design in France. Solar panels were found to negatively impact variables related to soil biodiversity and function (pedoclimatic, chemical, microbes and mesofauna).

Cesar and Aken (2025) tested negative impacts of solar panels by evaluating two different solar designs to investigate the trade off between energy yield and soil irradiance. Transparent solar panels were found to provide levels of ground irradiance to promote photosynthesis without increasing the footprint of the solar farm. These could pave a way forward with

agrivoltaic schemes and create a healthier soil microclimate allowing solar farms to enhance biodiversity.

Additional research has identified a cooling island effect of solar farms. This has been described by Guoqing et al (2021) and Xu et al (2024). Guoqing investigated how solar farms have potential to alter land surface temperatures by Landsat satellite imagery and confirmed using measurements in the field. They found a cooling effect up to 730m from the solar farms with the temperature cooling 2.3C within the closest 100m area. This finding demonstrates that there is a wider impact to adjoining land which needs to be considered to inform land management and with the expansion of solar farms a need to seriously consider appropriate siting. Xu et al (2024) reported not only the significant land surface cooling effect but also a detrimental effect on vegetation and albedo.

Hussain et al (2025) assessed the situation regarding determinants for planning permission of solar farms at local authority level within the England. Interestingly the environmental impacts of solar farms were found to barely matter for planning (or have likely already been dealt with by the time the proposal reaches the planning stage). In areas that are protected standardised guidance is adhered to however it was noted outside of that it ultimately becomes a decision of the planning authority in question, so there is a degree of inconsistency.

Impacts on ecosystem services

The combination of utilising solar power with provision for ecosystem services is an area where the literature is gaining in its evidence base. The concerns over land use are now prompting further investigation into the potential that solar facilities could provide in combination.

Treasure et al (2025) investigated the evidence for positive and negative impacts on ecosystem services globally for the entire life cycle of solar infrastructure from construction through to decommissioning. Within their dataset they found for the UK 22 documented impacts of which 13 were positive and 9 were negative. Those most significant from the wider dataset and applicable to the UK during the operational phase were; positive impacts - enhanced water cycle support, soil erosion regulation and pollination and negative impacts –

maintaining habitats and biodiversity. Positive impacts were more speculative, and further evidence from research across a range of former land uses, climates and ecosystems throughout the phases of the solar farm life stages would be beneficial to fill the data gap. However, the authors demonstrate that with an appropriately designed and managed solar farm there is the potential to enhance ecosystems services throughout the life cycle of the infrastructure project.

Enhancing the provision of ecosystem services using habitat enhancing strategies was modelled by Ludzuweit et al (2025) and found that by integrating vegetation such as grassland, hedges and trees within agrivoltaics that ecosystems service gains could be provided at a rate of 33-88% pollinator supply, 9-22% water retention, 7.5-20% sediment retention and up to 8% carbon storage.

There is a potential competition of land available for food production and energy, and whilst this is a debated topic experimental agrivoltaics experiments have been conducted where aloe vera, tomatoes, maize, pasture grass and lettuce have all successfully been grown under PV panels. Adeh et al (2019) found that the greatest solar PV power potential is achieved from croplands and dual use of this land could be used to address this competition.

Public concerns over land cover required for solar development persist, however data for the actual predictions of land cover required have been limited. Blaydes et al (2025) mapped current solar farm data across the UK and demonstrated that these cover a relatively small area. They determined that the majority of solar farms have been located on either arable land or improved grassland. Calculating an estimate of land required for future ground mounted solar farms (at 100%) for the 2050 target of 90GW would take up a proportion of just 0.72% of UK land and 1.5% of UK agricultural land. Given that solar infrastructure will increase and is likely to be embedded on and within agricultural land, the critical factor is that these solar farms should be used to enhance ecosystem services by providing a combination of land uses, food production and biodiversity conservation. Neesham-McTiernan et al (2025) provides a similar spatial assessment of the UK with an emphasis as to where agrivoltaics could be most beneficial providing large scale solar farms in synergy with agricultural needs.

A UK study investigated the use of solar farms to house honeybee hives by mapping the locations of existing solar farms and overlaying a 1.5km buffer for honeybee foraging. They estimated that if honeybee hives were installed at all existing solar parks in 2017 then the value of ecosystems services provided from pollination of those pollinator dependent crops, soft and top fruits would have reached £5.9 million and could provide many more times that (Armstrong et al, 2021). This could be further enhanced with appropriate planned crop production around areas of solar farms. The authors recommend that enhancing habitat for pollinators be considered further as they offer co-benefits in ecosystem services, land use and economic benefit.

Utilising technology and ecological systems in a mutually beneficial method is going to be key to the future development of solar energy facilities. Hernadez et al (2019) demonstrate that techno-ecological synergies (TESs) are not only feasible across a number of diverse environments but they also can support a number of ecosystems services. They developed a comprehensive framework of 16 TES that provided 20 potential beneficial outcomes.

Impacts on bats

The impacts of solar farms on bats are widely disputed and poorly understood, with mixed results reported. A recent study from the United States (Szoldatits, 2025) revealed a species specific difference in response to solar farms at ecovoltaic (combined electricity production and ecosystem services) sites with two species showing higher activity at the sites, where as another two species had no difference to the control sites. Montag et al (2016) conducted a comparative study that evaluated bat activity and diversity between solar plots and control plots. Eight sets of solar and control sites within the UK were surveyed. They found that there was no significant difference in bat species diversity between the two categories overall and when analysing the bat activity overall between all sites there was no significant difference, however there was a significant difference between three of the eight site pairs in number of bat passes per night. They conclude that bats do use solar farms at a comparable but possibly slightly lower level than control plots, although suggest they could provide an excellent foraging habitat that bats could become habituated to using. However, they also highlighted a number of limitations in their methodology that may confound results.

This positive impact of foraging provision was echoed by Szabadi et al (2023) which found a considerable amount of bat activity at solar farms and detected feeding buzzes indicating that the bats are foraging as well as commuting within the solar farms. The species composition at solar farms was observed to be similar to those found in either agricultural habitat or urban areas. In this study in Hungary this comprised primarily of *H. savii*, *N.noctula* and *P.kuhlii*. *Myotis* spp and *B.barbastellus* were not frequently recorded within the solar farms. They conclude that solar farms are particularly advantageous as a foraging opportunity for those bat species that are adapted to anthropogenic environments.

The negative impacts of solar farms have also been discussed recently (Barre et al 2023; Tinsley et al, 2023). Flight and feeding behaviour was studied at nine ground mounted utility size solar farms in the Rhone Vally in France by Barre and colleagues. They recorded three dimensional bat positions using paired sampling design with microphone arrays; one pair within the solar farm and one matched control located outside the solar farm. Echolocation calls were identified to species level where possible and speed of flight and feeding buzz probability was calculated. Strong behavioural impacts were observed on five of seven recorded species. The mean flight speed was found to be significantly higher and the trajectory straighter at solar sites than control sites. In addition, feeding buzz probability was significantly lower at the solar sites than the control sites and indicated that the quality of the foraging habitat was reduced. The researchers suggest that shading from panels may be reducing plant biomass and insect prey availability for the bats, however the authors recommend that further research is undertaken to enable understanding of the mechanism behind these negative impacts. Barre also noted that currently no data is available on the variation in abundance of nocturnal insects in response to solar farms, this would be key in determining availability and suitability of solar farms for foraging bats. Tinsley et al (2023) reported that ground mounted solar PV panels have a significant negative effect on bat activity. The researchers thoroughly compared the levels of bat activity and species richness between 19 operational solar farms spatially paired with 19 control sites within England. Echolocation data was collected via static detectors over a 7-night period at each solar farm and control site. Activity levels were determined by number of calls per hour and whether there was a difference between boundary and field locations and also any difference in species richness by generalised linear mixed effect modelling. The results from this recorded eight

species/groups and demonstrated that six of those species/groups (common and soprano pipistrelle, *Nyctallus* spp. *Myotis* spp. *Plecotus* spp. and serotine) had significantly lower activity levels. Implying that they were negatively impacted by solar panels. No difference in species richness was observed. Although useful information, this study provided information at a snap shot of time within the season, within which bat activity is likely to vary widely. In addition to that it was unclear whether the history of the management and relative age of the habitat was accounted for in the comparisons. It furthermore strengthens the need for more research into the impacts of solar panels on bats to understand this potential negative impact. Although the importance of providing an improved habitat surrounding solar farms to increase foraging habitat should be ensured to offset any unavoidable development of solar farms on sites with great feeding potential for bats.

Many studies refer back to the Nature communication publication by Greif and Siemers (2010) where they identified bats used innate echoacoustic cues for recognition of water bodies. This experimental design tested behaviour of 15 species of adult bat over 3 families; Minoptereridaen Verspertilionidae, and Rhinolophidae and in juvenile *M. emarginatus* and found via consecutive drinking attempts that they perceive horizontal acoustical mirrors to be water despite conflicting information. This implies that anthropogenic smooth horizontal surfaces can reflect sound for echolocating bats allowing them to interpretate it as a water body. As solar panels also polarise and reflect light this does highlight another risk to bats.

Fatalities of bats at solar farms was addressed by Smallwood (2022) where numbers were estimated from 11 solar photovoltaic sites were calculated at 0.06 fatalities/MW/year. This was considerably lower than the fatalities of bats found at Concentrated Solar Power (CSP) farms (5.49 fatalities/MW/year) and lower than birds indicating the risk of collision was much greater for birds than bats. However, this is another large gap in the knowledge base, as both activity and fatalities of bats at solar farms is not routinely monitored.

Impacts on birds

The fatalities of birds resulting at solar farms investigated by Smallwood (2022) provided a more concerning impact than for bats. The data for numbers of birds between 1982-2018 were analysed at 14 utility scale solar projects in California (11 of which were Photovoltaic

PV). The estimated number of fatalities/MW/year was found to be a mean of 11.61 in PV and 64.61 in found at Concentrated Solar Power (CSP) facilities. These estimates were consistently higher than ever previously reported. Birds were found to collide with solar panels, mirrors, transmission lines, fences and vehicles on site. Smallwood described how collisions with panels may be caused by a 'lake effect' – where birds may perceive a number of closely spaced PV panels as in fact a water body and attempt to land. This is of particular concern for migratory waterfowl and shorebirds. This study saw similar findings to an earlier one by Walston et al (2016) whereby the site with the panels located more closely together found water birds were over-represented within the impact trauma fatalities. The authors here also suggested that the polarising light may be attracting aggregations of insects in turn attracting insectivorous birds.

Yuzyk (2024) conducted a literature review focussing on summarising the global evidence on the impact of solar farms on birds. The findings conclude that to date the impact of solar on birds has a deficit of data and that so far evidence varies widely across different territories when addressing the aspects such as abundance, species composition and activity. Generally, bird diversity declines in areas with large solar infrastructure however CSP farms often support more species than in agricultural land. Bird mortality was demonstrated to be by collision with solar infrastructure (and burns from CSP plants), however much lower rates at PV. This mortality was higher at locations near wetlands or migratory routes making emphasis on location considerations key in future. Rooftop PV systems were suggested as a more biodiversity friendly alternative for birds.

Recently Copping et al (2024) addressed the impacts on birds within solar farms within the Fens, UK. Surveying six sites they found through their bird habitat evaluation modelling that the overall impact of solar energy on breeding bird habitat is expected to be small. In fact, where Nature Based Solutions are used in combination with woodland, Red and Amber listed Birds of Conservation Concern populations may see the largest increases in habitat availability, with only the farmland specialists seeing a decrease. This echoes previous findings of Montag et al (2016) that overall a higher diversity and abundance of birds of conservation concern utilise solar plots when compared with control plots. They also found that despite the fact skylarks would not nest within the solar farm they will forage within the area and on their

study two of the sites have significantly higher numbers of foraging skylarks than in the control plots, making them part of their territory. The authors conclude that solar farms may be able to provide a haven for declining species; notable species that they found only on solar plots included kestrel, stock dove, tawny owl, willow warbler and mallard. The use of solar farms by raptors is another area that warrants further research alongside longworth trapping studies to investigate the abundance and diversity of small mammals present.

The Barn Owl Trust (2024) has stated how ground mounted solar can indeed be beneficial to barn owls particularly where the vegetation underneath is maintained as rough grassland. It provides an opportunity for the barn owls to perch hunt from the solar panels which are of appropriate height and pose no danger to the owls.

The lack of design with a combined focus of energy production and wildlife were noted by Jarcuska et al (2024) where they recorded bird diversity at 32 solar parks all designed exclusively for electricity production. They found that solar parks provided habitat supporting greater total bird species richness and diversity, richness and abundance of insectivorous birds overall, whilst within grassland solar parks ground foragers were greater than their grassland control plots. However, had wildlife been a consideration during the design phase an even greater positive impact could have been achieved.

Impacts on invertebrates

The impacts on invertebrates have been a more thoroughly researched area within the solar infrastructure landscape. Generally, the consensus is that solar farms could provide a haven for invertebrates and make a concerted effort to conserve a number of species particularly pollinators. Positive impacts have been evidenced in the UK for butterflies, honeybees, bumblebees, hoverflies and moths (Blaydes, 2024).

Armstong et al (2021) made the case that solar farms could be a viable method to boost pollinator populations with honeybees in particular utilising them to for essential ecosystem services to fruit crops or oilseed. They also suggest that pollination service benefits should be included within the planning stage of solar farms.

In a modelling study within the UK Blaydes et al (2022) demonstrated that management of solar farms was key to supporting densities of bumble bees. Those managed as wildflower meadows throughout rather than just margins (or grassland) could double the number of foraging bumblebees in the surrounding landscape. They investigated how the shape, size and management alongside landscape context influenced ground nesting bumble bee density, nest density and nest productivity both inside existing solar farms and the surrounding landscape. The shape and size and landscape had little impact on bumble bee density within the solar farm however large, elongated resource rich solar farms were most effective at increasing density in the surrounding landscape. Field data however is essential to test these findings.

Randall-Boggis et al (2019) found significantly greater abundance of butterflies was observed in solar parks managed with grazing and meadows compared to control sites. There was a significantly higher abundance of bees associated with solar parks manged by planting or maintaining wild flower and nectar seed meadows compared to control sites. Species richness of butterflies and bees was greater in solar parks compared to control sites, however they found that management actions had no significant difference to the species richness. An experimental study in solar parks in Hungary (Tölgyesi et al, 2024) found that introducing a species rich grassland could increase total plant richness and grassland species richness more than the control sites and had higher species richness of pollinators - hoverflies and wild bees.

A couple of literature reviews focussed on discrete management practices for invertebrates (Barley et al 2025; Blaydes et al 2021) and found a difference in opinion. Barley summarises how energy infrastructure such as solar and rights of way could provide ideal opportunities for conservation of insects. They discuss how co-locating high quality insect habitat within infrastructure (which is generally within farming landscapes) can jointly meet both conservation needs with agricultural production needs. Blaydes assessed 185 articles for details on how 27 management interventions in Europe can enhance pollinator biodiversity. From this assessment of evidence, they then provided recommendations of improvements to solar farm management to enhance pollinator biodiversity by utilising considered management practices, provision of foraging and reproductive resources, and increasing the heterogeneity, connectivity and microclimatic variation of the landscape within them.

Polarising light from the solar panels and its impacts on aquatic invertebrates has been reported by several researchers. Egri et al (2016) in a study conducted in Budapest found that horizontally polarised light even ten times dimmer was more attractive in the springtail *Podura aquatica* than unpolarised light. Fakas et al (2016) also found the same response in two mayfly species where horizontally polarised light was consistently found more attractive than vertically polarised or unpolarised light in study in Hungary. Here they detailed that the avoidance of weak vertical polarised light from aquatic vegetation allows them to avoid the edges of water bodies and lay eggs appropriately in the water. The negative effect of attraction of polarised light from solar panels has also previously been reported to initiate oviposition behaviour in mayflies (Ephemeroptera), stoneflies (Trichoptera), dolichopodid dipterans, and tabanid flies (Tabanidae), where solar panels were found to reflect far more than natural water sources (Horvath et al, 2010). Siting of solar farms near water bodies warrants further consideration on its impact on aquatic invertebrate populations.

Negative impacts were also demonstrated on tenebrionid beetles in a study in the Mojave Desert where the more intensive solar development using bulldozing had significant effects on the beetle abundance, species richness and diversity (Grodsky et al, 2024). This family of beetles has 20,000 species worldwide with 47 species in Britain.

Previous overall impact literature reviews

There have been numerous literature reviews of available data conducted regarding solar farms impacts on biodiversity so far - 21 were reviewed just during this literature review. These reviews have covered a range of topics regarding the impacts including; general biodiversity (Esteves, 2016; Lafiitte et al, 2023; Matwani & Ojija, 2025; Meletiou et al, 2019; Taylor et al, 2019), birds (Yuzyk, 2024), invertebrates (Barley et al, 2025; Blaydes et al, 2021), soils (Carvalho et al, 2024; Vaughan & Brent, 2024), vegetation/hydrology/agrivoltaics (Nordberg et al, 2021; Vaughan & Brent, 2024; Walston et al, 2022; Yavari et al, 2022), artificial habitats (Boscarino-Gaetano et al, 2024), wildlife behaviour (Chock et al, 2020) general ecology (Dhar et al, 2020) and ecosystem services (Oudes et al, 2022). Some of these have been discussed within their relevant field as above.

The most recent literature review published this month by Fleming (2025) described five key mechanisms explaining the attractiveness or avoidance of solar facilities by birds, bats and invertebrates, detailed below:

- Lost, altered and novel habitat
- Evaporation ponds
- Increased foraging opportunities
- Concentrated solar energy
- Solar panels represent large expanse of smooth flat surfaces

Dealing with Concentrated Solar Power (CSP) and Solar Photovoltaic (PV) systems separately through a thorough review of 101 articles they found that both positive and negative impacts had been reported. Contrasting results were found for impacts over the species groups particularly with birds where species richness was reported to be less, no difference and more at solar facilities within various studies.

A little discussed factor in the future of renewable energy siting was addressed by Ashraf et al (2024) whereby they reviewed literature for evidence of where species range shifts from climate change impacts have been considered. They discovered within a data set of 157 publications (between 1997 and 2022) that whilst 93% of these addressed biodiversity, only 18.4% considered the role of climate change on biodiversity and furthermore only 1.9% of these investigated the role of climate change as a driver to range shifts for biodiversity/taxonomic group or species of interest. This lack of data is an area where research should be focussed to provide as climate change threatens the range of more of our species.

Delahay and Sherman (2023) summarised the published evidence to date regarding the impacts of solar farms on biodiversity and found a total of 57 articles comprising of 33 published papers, 15 reports and 9 miscellaneous grey literature items. Although their search utilised a twenty year period from 2002 to 2022 the increase in articles rose dramatically in the last three years of that search period. This demonstrates that the evidence base for impacts on biodiversity is rapidly increasing and will enable these considerations to inform future planning and management of solar farms. However, they concluded that currently

empirical data is still vastly lacking to enable comprehensive best practice guidance on enhancing solar sites for biodiversity or avoidance of impacts on species.

Natural England previously published an evidence review by Harrison et al (2017) stating how concerning the lack of evidence there is on the ecological impact of solar farms. Taylor et al (2019) conducted their second comprehensive review of research into the ecological impacts of ground mounted solar sites in the UK and found in the 5 years intervening little had changed. Between these and all subsequent reviews the case remains the same, they detail the lack of data and consistently identify a range of key areas for further research – however despite the recent influx (refer to Figure 1) to date not many of these key focus areas have been addressed.

Biodiversity Net Gain

Benbouzid and Simon (2025) reviewed 30 planning application submissions in the UK and assessed biodiversity net gain. The study highlighted the issue that there are areas within the NPPF that allow for differing interpretations between planning authorities. They did demonstrate through a case study that a biodiversity net gain of up to 70% can be achieved and suggest that more explicit criteria and consultation prior to application would enhance biodiversity and provide renewable energy in an integrated nature positive approach.

There was no significant evidence published of the potential for solar farms to provide Biodiversity Net Gain although many positive impacts on biodiversity have been described.

Guidance and information on design and management

A collaboration between Lancaster University and the University of York developed a Solar Park Impacts on Ecosystem Services (SPIES) decision support tool (DST) in 2019 described by Randall-Boggis et al (2020). This comprised an assessment of 704 pieces of evidence including 457 peer reviewed journal articles assessing the impact of land management on ecosystem services. This tool was tested with operational solar parks and then validated with nine further solar parks. Use of this could further assist in future plans for solar farms.

Parker & Monkhouse (2022) and Solar Energy UK (2022) have published guidance on increasing biodiversity and recommendations on how to monitor it. These documents provide a host of information for solar farms and provide essential reading prior to design to assist with planning and life span of the project. The Before-After-Control-Impact (BACI) approach – this examines the conditions before (pre-construction) and after (post-construction) of the site whilst also comparing a Control site with the Impact site and then attributing the ecological changes due to the impact (Green, 1979; Stewart-Oaten et al, 1986) should be employed to facilitate the recommended monitoring. Sinha et al (2018) have also described best practices for improving biodiversity at utility scale solar facilities evidenced by biological monitoring efforts at the Topaaz project, California. This case study details design features to enhance the environment for endangered species with management systems to combine increase in biodiversity with effective operation of the site.

Designs must also account for the lifecycle emissions, land use and community impact. Solar whilst having lower operational emissions does however have a larger land footprint than wind systems. Although the Copping et al (2024) study demonstrated that renewable energy deployment in terms of solar requires relatively little land and impacts on food production would be minimal. Tinsley et al (2024) having reviewed the spatial locations of solar farms within England reiterate the importance of revolving research around biodiversity and solar farms is not only incorporated into decision making of the operational design but that monitoring is completed for the whole lifespan of the solar farms to assess impacts. Barley et al (2025) acknowledge the gaps in research around co-locating habitat with solar infrastructure and detail the urgency of action to generate more insect conservation gains, given the exponential growth in this energy sector. This requires site specific planning as well as plant and pollinator monitoring to become successful.

Although there is an immediate need for ground mounted solar, data provided from University College London (UCL) to CPRE has identified that consideration of alternative locations for installing solar panels such as on new buildings, existing warehouses and car parks could provide 40-50GW, representing more than half the national target of 70GW (CPRE, 2023). This is another factor that should be considered within the planning system.

5 Research gaps and future directions

The impacts of ground mounted solar on biodiversity overall and for individual species groups is an area that is still vastly lacking in empirical evidence. Furthermore, evidence for specific countries with similar climate, legislation and best practice guidance is a requirement to develop the sector in a more consistently nature positive route.

Considerations of the impacts of ground mounted solar panels on both plants and soils must be contextualised to the local conditions and factored before, during and after the development of the solar farm (Carvalho et al 2025). In addition, other variables such as previous land use, land management the inter-panel gap, panel height and angles should all be addressed in further research to maximise positive biodiversity outcomes. Further research into the variability of the diversity of plants in association with the microclimate variability under the panels, between panels and in control areas away from panels as well as comparing between within and outside solar parks is critical (Makaronidou, 2020).

The necessity for further research into wildlife-solar facilities behavioural interactions was highlighted by Chock et al (2020) to inform on how to site, design and operate solar facilities whilst reducing negative impacts. This will require collaboration between sectors and a more systematic and standardised approach to monitoring before, during and after solar farm construction and operation with appropriate control sites.

From the literature review the following areas have been highlighted numerous times as critical research gaps to address and inform our rapid expansion into delivering solar across the UK:

- Experimental studies of optimising plant diversity between and beneath panels
- Experimental studies of impacts of polarised light on birds and invertebrates
- Experimental long term data on wildlife impacts from UK solar farms using BACI approach
- Evidence of Biodiversity Net Gain provision from solar projects
- Quantifying the impact of polarising light pollution on migratory routes

- Monitoring (all species) – from pre-construction through to decommissioning
- Bats in situ data on impacts – foraging, orientation, drinking attempts, collision
- Birds in situ data on impacts – feeding, nesting, perching, collision
- Invertebrates – attraction to panels (aquatic and oviposition), abundance, nocturnal species (bat prey species), pest predator invertebrate species
- Impacts on other species – reptiles, brown hares, small mammals, birds of prey
- Climate change impacts on species range distribution mapped against solar
- Impacts of historical land use on soils

6 Conclusion

Large scale ground mounted solar infrastructure can have varying impacts on a wide range of species. The negative impacts on biodiversity have been demonstrated as being;

- fragmentation and loss of habitat (current or climate change driven range of species)
- polarising of light resulting in alteration of behaviour – attracting species
- changes in soil health
- bird collisions
- reduced foraging for bats

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More positive impacts are the potential;

- enhanced invertebrate habitat - therefore increasing foraging sources for insectivores
- increased pollination for ecosystem services
- provision of mosaic of habitats relatively undisturbed for many species
- opportunity for agrivoltaics

Many of these positive and negative impacts overlap with inconclusive findings for each. From this review of research published 2015-2025 it has been found that there is still a substantial gap in evidence of the ecological impacts of ground mounted solar facilities. With regards to the UK only 8 publications provide any empirical evidence with key indicator species groups bats, birds, and invertebrates. Globally evidence has conflicting opinions on the level and direction of the impact on biodiversity on key features. However, there is a general consensus that solar farms offer an opportunity for biodiversity enhancement, with thoughtful planning, management and monitoring in place. Numerous studies have made suggestions for design and management at solar facilities to increase biodiversity within them and there are two published best practice documents in the UK which detail management and monitoring recommendations. However further research is critical to fully understanding the impacts of solar on biodiversity and the case has been made repeatedly for more BACI assessments to be made to aid the development of this evidence base.

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8 Appendix

Authors	Title	Journal	Publication date	Item type	DOI	Design/ Management	Impact on Features	Primary data	Region
Adeh, E.H., et al	Solar PV Power Potential is Greatest Over Croplands	Scientific Reports	2019	Journal article	10.1038/s41598-019-47803-3	Yes	Ecosystem services	Yes	USA
Armstrong, A., et al	Honeybee pollination benefits could inform solar park business cases, planning decision and environmental sustainability targets	Biological Conservation	2021	Journal article	10.1016/j.biocon.2021.109332	Yes	Ecosystem services, invertebrates (pollinators)	Yes	England
Ashraf, U., et al	Aligning renewable energy expansion with climate-driven range shifts	Nature Climate Change	2024	Journal article - review	10.1038/s41558-024-01941-3	Yes	Biodiversity	No	Global

Barley, T.A., et al	A stitch in time: integrating energy infrastructure into the fabric of conservation habitats	Current Opinion in Insect Science	2025	Journal article - review	10.1016/j.cois.2025.101358	Yes	Invertebrates (pollinators)	No	Global
Barre, K., et al	Insectivorous bats alter their flight and feeding behaviour at ground mounted solar farms	Journal of Applied Ecology	2023	Journal article	10.1111/1365-2664.14555	Yes	Bats	Yes	France
Benbouzid,I and Simon, D	Evaluating the potential for improving biodiversity in solar farms	Royal Holloway University	2025	PDF Research Report	evaluating-the-potential-for-improving-biodiversity-in-solar-farms.pdf	Yes	Biodiversity	Yes	UK
Blaydes, H., et al	Opportunities to enhance pollinator biodiversity in solar parks	Renewable and Sustainable Energy Reviews	2021	Journal - review	10.1016/j.rser.2021.111065	No	Insects (pollinators)	No	Europe

Blaydes, H., et al	Solar park management and design to boost bumble bee populations	Environmental Research	2022	Journal article	10.1088/17 48- 9326/ac584 0	Yes	Invertebrates (pollinators)	Yes	UK
Blaydes, H., et al	On-site floral resources and surrounding landscape characteristics impact pollinator biodiversity at solar parks	Ecological Solutions and Evidence	2023	Journal article	10.1002/2688-8319.12307	Yes	Invertebrates (pollinators)	Yes	UK
Blaydes, H., et al	Shedding light on land use change for solar farms	Progress in Energy	2025	Journal article	10.1088/2516-1083/adc9f5	No	Ecosystem services – agricultural land use	Yes	UK
Boscarino-Gaetano, R., et al	Creating wildlife habitat using artificial structures: a review of heir efficacy and	Biological Reviews	2024	Journal article - review	10.1111/brv.13095	Yes	Biodiversity	No	Global

	potential use in solar farms								
Carvalho, F., et al	Enhancing soil carbon in solar farms through active land management: a systematic review of the available evidence	Environmental Research	2024	Journal article - review	10.1088/2752-664X/ad8ce4	Yes	Soil	No	UK
Carvalho, F., et al	Plant and soil responses to ground-mounted solar panels in temperate agricultural systems	Environmental Research	2025	Journal article	10.1088/1748-9326/ada45b	Yes	Soil, plants	Yes	UK
Cesar, I., & Van Aken, B.B.,	Evaluation method and module design for cost-effective compliance with irradiance guidelines to	EPJ Photovoltaics	2025	Journal article	10.1051/epjpv/2025003	Yes	Soil	Yes	Netherlands

	maintain soil quality in solar parks								
Chock, R.Y., et al	Evaluating potential effects of solar power facilities on wildlife from an animal behaviour perspective	Conservation Science and Practice	2020	Journal article	10.1111/csp2.319	Yes	Wildlife - behaviour	Yes	Global
Copping, J.P., et al	Ambitious onshore renewable energy deployment does not exacerbate future UK land-use challenges.	Cell Reports Sustainability	2024	Journal article	10.1016/j.crsus.2024.100122.	Yes	Land use, food production, birds	Yes	UK
Copping, J.P., et al	Solar farm management influences breeding bird responses in an arable-	Bird Study	2025	Journal article	10.1080/00063657.2025.2450392	Yes	Birds	Yes	UK

	dominated landscape								
Delahay R. and Sherman, D.	A summary of the published evidence on the impacts of solar farms on biodiversity	EDF Renewables Report	2023	Report - review	Solar-Panels-and-Wildlife-Review-2019.pdf	No	Biodiversity Multi species	No	Temperate regions
Dhar, A., et al	Perspectives on environmental impacts and a land reclamation strategy for solar and wind energy systems.	Science of the total environment	2020	Journal article - review	10.1016/j.scitotenv.2019.134602	No	Biodiversity Birds	Yes	Global
Egri, Á., et al	Polarization sensitivity in Collembola: an experimental study of polarotaxis in the water-surface-inhabiting	Journal of Experimental Biology	2016	Journal article	10.1242/jeb.139295	Yes	Aquatic invertebrates	Yes	Hungary

	springtail,*Podura aquatica*.								
Esteves, A.M.R.,	Untapping the full potential of solar farms in the UK: Different Approaches to Management	Instituto Politecnico de Braganca (Portugal)	2016	Dissertation - review	ProQuest Dissertations & Theses, 2016. 30207618	Yes	Biodiversity	No	UK
Farkas, A.,	Mayflies are least attracted to vertical polarization: A polarotactic reaction helping to avoid unsuitable habitats	*Physiology & Behavior*	2016	Journal article	10.1016/j.physbeh.2016.05.009	Yes	Aquatic invertebrates	Yes	Hungary
Fleming, P.A.	All that glitters – Review of solar impacts on fauna	Renewable and Sustainable Energy Reviews	2025	Journal article – review	10.1016/j.rser.2025.115995	Yes	Birds, bats, wildlife	No	Global

Guoqing, L., et al	Ground-mounted photovoltaic solar parks promote land surface cool islands in arid ecosystems	Renewable and Sustainable Energy Transition	2021	Journal article	10.1016/j.rset.2021.100008	Yes	Habitat	Yes	China, United States
Grodsky, S.M., et al	Mixed responses of tenebrionid beetles to solar energy development in the Mojave Desert	Journal of Arid Environments	2024	Journal article	10.1016/j.jaridenv.2024.105243	Yes	Insects	Yes	United States
Harrison, C., et al	Evidence review of the impact of solar farms on birds, bats and general ecology	Natural England report NEER012	2017	Report – evidence review	Evidence review of the impact of solar farms on birds, bats and general ecology 2016 - NEER012	No	Birds, bats, biodiversity	No	Global
Hernandez,R.R., et al	Techno-ecological synergies of solar energy produce outcomes that mitigate global change	Nature Sustainability	2019	Research article	10.1038/s41893-019-0309-z	Yes	Ecosystem services	Yes	Global

Hernandez,R.R., et al	Simulated photovoltaic solar panels alter the seed bank survival of two desert annual plant species	Plants	2020	Research article	10.3390/plants9091125	No	Plants	Yes	United States
Hussain, M.M., et al.,	"Here comes the sun": Determinants of solar farm planning at local authority level in England.	Energy Research & Social Science	2025	Research article	10.1016/j.erss.2024.103916	Yes	Biodiversity	Yes	England
Jarčuška, B., et al	Solar parks can enhance bird diversity in agricultural landscape	Journal of Environmental Management	2024	Journal article	10.1016/j.jenvman.2023.119902	No	Birds	Yes	Slovakia
Lafitte, A., et al	Existing evidence on the effects of photovoltaic panels on biodiversity: a	Environmental Evidence	2023	Journal article - review	10.1186/s13750-023-00318-x	No	Biodiversity – wild terrestrial and semi-	No	Global

	systematic map with critical appraisal of study validity						aquatic species		
Lambert, Q., et al	Photovoltaic power stations: an opportunity to promote European semi-natural grasslands?	Frontiers in Environmental Science	2023	Journal article	10.3389/fenvs.2023.1137845	Yes	Grasslands, soils	Yes	France
Lambert, Q., et al	Effects of habitat restoration and solar panels on soil properties and functions in solar parks	Applied soil ecology	2024	Journal article	10.1016/j.apsoil.2024.105614	No	Soil	Yes	France
Ludzuweit, A., et al	Enhancing ecosystem services and biodiversity in agrivoltaics through habitat-	Renewable and Sustainable Energy Reviews	2025	Journal article	10.1016/j.rser.2025.115380	No	Ecosystem services Insects (pollinators)	Yes	Germany

	enhancing strategies								
Makaronidou, M.,	Assessment on the local climate effects of solar photovoltaic parks	ResearchGate	2020	PhD thesis	10.17635/lancaster/thesis/1019	No	Grassland	Yes	UK
Matwani, J., and Ojija, F.,	Exploring the link between energy resources and global biodiversity.	Sustainable Social Development	2025	Journal article - review	10.54517/ssd3245	No	Biodiversity	Yes	Global
Meletiou, A., et al	EU renewable energy policies, global biodiversity, and the UN SDGs	Centre for Ecology & Hydrology, UK	2019	Report - review	(PDF) EU renewable energy policies, global biodiversity, and the UN SDGs-A report of the EKLIPSE project	No	Biodiversity	No	Global
Montag, H., et al	The Effects of Solar Farms on Local Biodiversity: A comparative study	Clarkson & Woods and Wychwood Biodiversity	2016	Report	Clarkson & Woods	Yes	Botany, invertebrates, birds, bats, biodiversity	Yes	UK

Neesham-McTiernan, T.H., et al	The spatial potential for agrivoltaics to address energy-agriculture land use conflicts in Great Britain	Applied Energy	2025	Journal article	10.1016/j.apenergy.2025.125527	Yes	Botany, combined land use - agrivoltaics	Yes	UK
Nordberg, E.J., et al	Designing solar farms for synergistic commercial and conservation outcomes	Solar Energy	2021	Journal - review	10.1016/j.solener.2021.09.090	Yes	Biodiversity	No	Global
Oudes, D., and Stremke, S.,	Next generation solar power plants? A comparative analysis of frontrunner solar landscapes in Europe	Renewable and Sustainable Energy Reviews	2021	Journal article	10.1016/j.rser.2021.111101	No	Ecosystem services	Yes	Europe but some UK case studies
Oudes, D., et al	Towards a typology of solar energy	Energy Research & Social Science	2022	Journal article –	10.1016/j.erss.2022.102742	Yes	Ecosystem services	Yes	Europe but some UK case studies

	landscapes: Mixed-production, nature based and landscape inclusive solar power transitions			review and case studies					
Parker, G., and Monkhouse, J.,	Realising the Biodiversity Potential of Solar Farms – A Practical Guide	Naturesave Insurance	2022	Practical guide	realising-the-biodiversity-potential-of-solar-farms.pdf	Yes	Biodiversity	No	UK
Randle-Boggis, R.J.,et al	Realising co-benefits for natural capital and ecosystem services from solar parks: A co-developed, evidence-based approach	Renewable and Sustainable Energy Reviews	2020	Journal article	10.1016/j.rser.2020.109775	Yes	Ecosystem services	Yes	UK
Sinha, P., et al	Best Practices in Responsible Land Use for Improving	Case Studies in the Environment	2018	Journal article	10.1525/cse.2018.001123	Yes	Biodiversity	Yes	USA

	Biodiversity at a Utility-Scale Solar Facility								
Smallwood, K.S.	Utility-scale solar impacts to volant wildlife	Journal of Wildlife Management	2022	Jornal article	10.1002/jwmg.22216	No	Birds, bats	Yes	USA
Solar Energy UK	A Standardised Approach to Monitoring Biodiversity on Solar Farms	Solar Trade Association	2022	Guidance	Ecological-Monitoring-Guidance-2022.pdf	Yes	Biodiversity	No	UK
Stott, H.L.	Microclimatic and diversity controls on UK grassland carbon cycling	Lancaster University	2017	PhD thesis	2017HeatherStottPhD.pdf	No	Grasslands	Yes	UK
Szabadi, K.L., et al	The use of solar farms by bats in mosaic landscapes: Implications for conservation	Global Ecology and Conservation	2023	Journal article	10.1016/j.gecco.2023.e02481	No	Bats	Yes	Hungary

Szoldatits et al	Bat Activity at Ecovoltaic Solar Energy Developments in the Midwestern United States	Not peer review published	2025	Preprint research paper	Bat Activity at Ecovoltaic Solar Energy Developments in the Midwestern United States	No	Bats	Yes	USA
Taylor, R., et at	Potential ecological impacts of ground-mounted photovoltaic solar panels	BSG Ecology	2019	Report - literature review	Solar-Panels-and-Wildlife-Review-2019.pdf	No	Biodiversity, bats, birds, aquatic invertebrates	No	Global
Tinsley, E., et al	Renewable energies and biodiversity: Impact of ground-mounted solar photovoltaic sites on bat activity	Journal of Applied Ecology	2023	Journal article	10.1111/1365-2664.14474	Yes	Bats	Yes	UK
Tinsley, E., et al	The location of solar farms within England's ecological landscape:	Journal of Environmental Management	2024	Journal article	10.1016/j.jenvman.2024.123372	Yes	Biodiversity	Yes	England

	Implications for biodiversity conservation								
Tölgyesi, C.,	Introducing the first ecovoltaic parks of Hungary: a reconciliation between solar development and nature conservation,	EGU General Assembly	2024	Poster/ presentation	10.5194/egusphere-egu24-2933	Yes	Ecosystem services	Yes	Hungary
Treasure, L., et al	Global assessment of solar park impacts on ecosystem services	Progress in Energy	2025	Journal article - review	10.1088/2516-1083/addfa4	Yes	Ecosystem services	No	Global
Uldrijan, D., et al	Bioindication of Environmental Conditions Using Solar Park Vegetation	Environments	2023	Journal article	10.3390/environments10050086	Yes	Soil, botany	Yes	Czech Republic

van der Haas, I.,	Solar park biodiversity: pollinator abundance in different locations with seed mixtures	AERES University of Applied Sciences, Almere	2019	PDF Research Report	Solar park biodiversity:pollinator-abundance-in-different-locations-with-seed-mixtures.pdf	Yes	Insects (pollinators)	Yes	Netherlands
Vaughan, A., and Brent, B,.	Agrivoltaics for small ruminants: A review	Small Ruminant Research	2024	Journal article - review	10.1016/j.smallrumres.2024.107393	Yes	Ecosystem services, soils	No	Global
Walston, L.J., et al	A preliminary assessment of avian mortality at utility-scale solar energy facilities in the United States.	Renewable Energy	2016	Journal article	10.1016/j.renene.2016.02.041	Yes	Birds	Yes	USA
Walston, L.J., et al	Opportunities for agrivoltaic systems to achieve synergistic food-energy-environmental needs and	Frontiers in sustainable food systems	2022	Journal article - review	10.3389/fsufs.2022.932018	Yes	Ecosystem services, biodiversity	No	Global

	address sustainability goals.								
Xu, Z., et al	A global assessment of the effects of solar farms on albedo, vegetation and land surface temperature using remote sensing	Solar Energy	2024	Journal article	10.1016/j.solener.2023.112198	Yes	Habitat, vegetation	Yes	Global
Yavari, R., et al	Minimizing environmental impacts of solar farms: a review of current science on landscape hydrology and guidance on stormwater management	Environmental Research: Infrastructure and Sustainability	2022	Journal article - review	10.1088/2634-4505/ac76dd	Yes	Soil, plants, hydrology	Yes	USA

Yuzyk, A.V.,	Global Insights of the Impact of Solar Power Plants on Bird Populations	Biodiversity, Ecology and Experimental Biology	2024	Journal article - review	10.34142/2708-5848.2024.26.1.06	No	Birds	No	Global
Zhao, L., et al	Soil microbial networks' complexity as a primary driver of multifunctionality in photovoltaic power plants in the northwest region of China	Frontiers in Microbiology	2025	Journal article	10.3389/fmicb.2025.1579497	No	Soil	Yes	China
Zheng, J., et al	An observational study on the microclimate and soil thermal regimes under solar photovoltaic arrays	Solar Energy	2023	Journal article	10.1016/j.solener.2023.112159	No	Soils	Yes	China